SCIENCE

OCTOBER 6, 1950

ANNUAL EQUIPMENT ISSUE

INSTRUMENTATION FOR RADIOACTIVITY

THE REFLECTING MICROSCOPE

AMPLIFYING AND INTENSIFYING FLUOROSCOPIC IMAGES

SYMBOLIC LOGIC AND LARGE-SCALE CALCULATING MACHINES

THE TRAVELING-WAVE LINEAR ACCELERATOR

COMPLETE TABLE OF CONTENTS ON PAGE 3

VOLUME 112, NUMBER 2910

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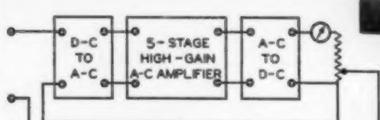

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SCIENCE

Vol. 112 No. 2910 Friday, October 6, 1950

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Science, founded in 1880, is published each Friday by the American Association for the Advancement of Science at the Business Press, 10 McGovern Ave., Lancaster, Pa. Entered as second-class matter at the Post Office at Lancaster, Pa., January 13, 1948, under the Act of March 3, 1879. Acceptance for mailing at the special rate postage provided for in the Act of February 28, 1925, embodied in Paragraph (d-2) Section 34.40 P. L. & R. of 1948.

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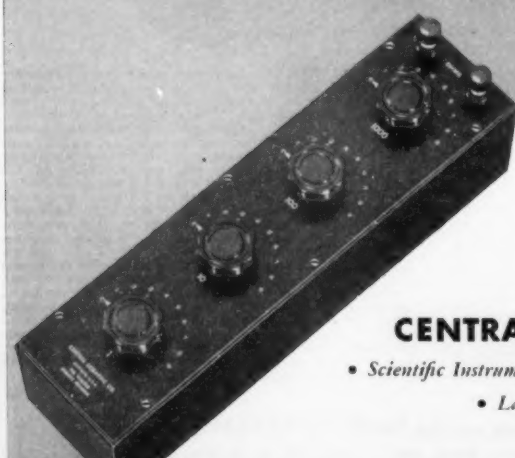

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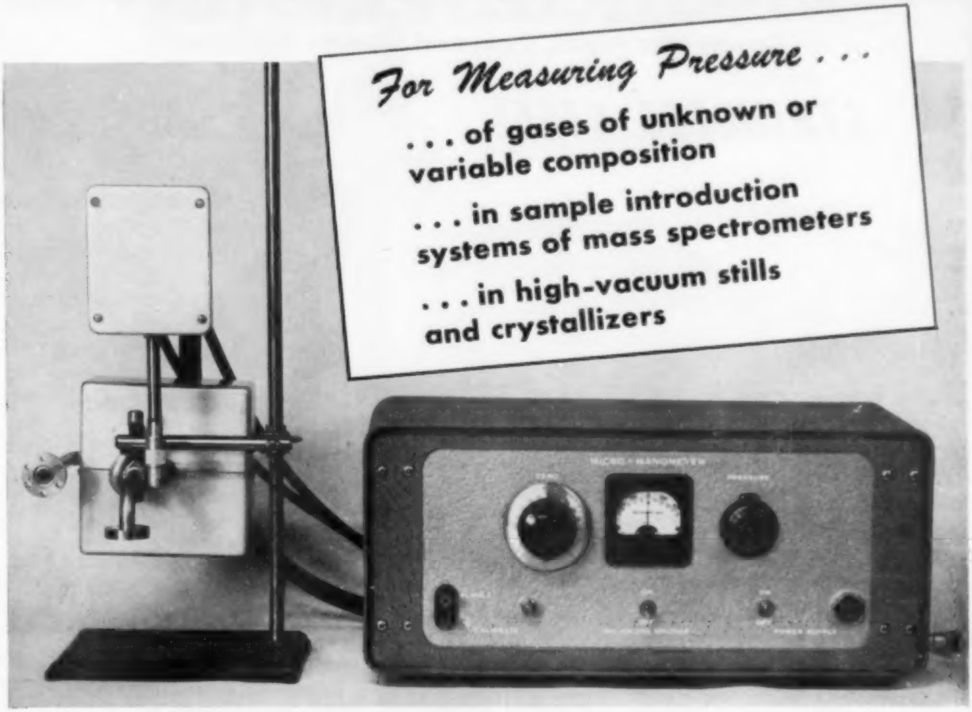

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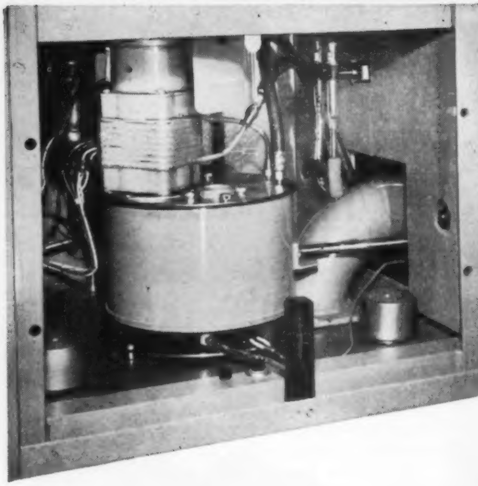

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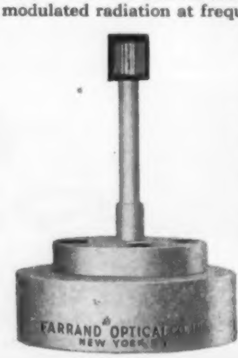

BULLETIN 805 ON REQUEST

FARRAND OPTICAL CO., Inc.

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Instrumentation for Radioactivity[1]

George F. Pieper[2]

Tracerlab, Inc., Boston, Massachusetts

WITH THE ADVENT of the nuclear chain-reacting pile as a result of wartime research in the field of atomic explosives, an extremely important tool became available for widespread use shortly after the close of the war. The immediate large-scale availability of radioactive isotopes, the by-products of bomb manufacture, has paved the way for the introduction of new methods and tools into industry, methods that may well enable us to deal simply with problems hitherto insoluble, tools that high costs have previously confined to the research laboratory.

The usefulness of radioactivity stems from its ability to make its presence known through the disintegration of unstable nuclei, with the emission of energy in the form of electromagnetic radiation or high-speed particles. Regardless of the particular application of a radioactive isotope, suitable means must be employed to establish the amount of activity present, or to determine what changes have occurred in the flux of radiation at a given surface in space as a result of other factors—for example, changes in geometry or changes in interposed absorbing material. The purpose of this paper is to review briefly the instruments required for the detection of the presence of radioisotopes. A number of excellent articles (*1*) that cover this subject, or sections of it, more thoroughly can be found in the literature. Several texts (*7*) also have chapters devoted to various phases of instrumentation.

The most common forms of radiation-detecting devices are based upon the ionization produced in gases by quanta and high-speed particles. Of these detectors, the simplest is the ionization chamber. This is an electrical device that measures the number of ion pairs produced by a particle or quantum in passing between two electrodes. Although any shapes may be used, most commonly the electrodes are constructed in cylindrical or plane parallel geometry, and an appropriate fill-gas is enclosed in the space between them. If such a chamber is exposed to a constant intensity of radiation, and the ionization current is measured as a function of the voltage applied between the electrodes, the current is found to increase with voltage quasi-exponentially to a constant value, a result of the phenomenon of recombination. When the fraction of ions lost by recombination goes to zero, a saturation condition is reached at which no further increase in current is obtained with moderate increase in voltage. Ionization chambers are most frequently operated in the saturation region, because here fluctuations in voltage are not important.

Ionization chambers may be used to record the passage of a single particle through them; in fact, they are able to distinguish between different types of radiation as a result of the different ionizing abilities of the various nuclear emissions. In this case the shape of the voltage pulse that appears on the collector electrode is extremely important. More frequently, chambers are used to measure the average ionization current resulting from a steady flux of radiation. Here statistical variations in the average current are observed, and these variations depend for their magnitude on the average radiation flux and the time constant of the chamber circuit.

If the ionization produced by alpha particles is to be measured in an ionization chamber, the "window" through which the alphas are introduced must be very thin, certainly less than 5 mg/cm^2. Thin sheet mica or stretched nylon or Zapon films about 1/10,000 inch thick, made conducting by a negligibly thin coat of colloidal graphite, make satisfactory alpha chamber windows. Such chambers operate at atmospheric pressure; hence the window will not be subject to a pressure differential. The problem in designing a chamber for use with beta particles is not one of window thickness (unless very low-energy particles are being measured), but is rather one of obtaining a maximum energy absorption in the gas. Ionization currents can be increased by the use of dense gases at high pressure, but even then only a fraction of the energy of a fast beta particle is expended in gas ionization in a chamber of average size. Still different considerations dictate the design of a high-efficiency gamma ray ionization chamber. Here interest lies in converting the photons into high-speed electrons by means of the photoelectric effect, Compton effect, and pair production. These electrons will then produce ion pairs in the fill-gas. To have an efficient gamma-

[1] The advice and encouragement of Eric T. Clarke and Marvin G. Schorr in the preparation of this paper are gratefully acknowledged.

[2] Now at Sloane Physics Laboratory, Yale University, New Haven, Conn.

to-electron conversion, the window should be of a material having a large gamma-ray absorption coefficient, such as tantalum, tungsten, or lead, and the thickness of the window should be approximately equal to the range of the most energetic secondary electron.[3] For still higher efficiency, the chamber may contain added plates similar to the window.

Almost any gas may be used as a fill-gas in an ionization chamber; in general, the densest ionization conveniently obtainable is desired in the gas. This can be achieved by the use of argon or krypton, at high pressures if necessary. For air at atmospheric pressure, a field of several hundred volts per centimeter between the electrodes is needed to establish a saturation condition. Smaller field strengths are required for saturation in very pure gases, such as hydrogen, nitrogen, and the inert gases in which negative ions are not formed by electron attachment. In purified argon (not ordinary tank argon) at pressures of 7 atmospheres a field of only 70 volts/cm is necessary (*6*), although the field strength required for saturation increases rapidly with increasing gas pressure.

A proportional counter is an ionization chamber in which the number of ion pairs is increased by collision in a region of high electric field. Such counters are most useful when the initial ionization is lower than that which can be measured by using an ionization chamber, or when it is desired to detect one type of radiation in the presence of another. If an ionizing particle passes through the gas of a cylindrical proportional counter with a positive center wire, the electrons will be forced toward the wire by the low field (proportional to $1/r$) until they reach the immediate vicinity of the center wire. In the large field near the wire, the initial electrons will produce other electrons by collisions with the gas atoms or molecules, and avalanches will occur. For each initial electron, A electrons will reach the wire, where A is called the gas amplification factor. It should be noted that the voltage pulse on the center wire arises from the motion of the positive ions formed in the avalanche as they move away from the wire, producing a pulse with a very short rise time because electrons are produced too close to the wire (within a few mean free paths) to give rise to any appreciable induced voltages. The gas multiplication factor A will usually have a value of the order of 10^3; hence an alpha particle that produces about 10^5 ion pairs and a beta particle giving rise to, say, 100 ion pairs, will produce pulses corresponding to 10^8 and 10^5 ions, respectively. A discriminator in the associated electronic circuit can easily be adjusted to detect alpha particles in the presence of high intensities of beta and gamma radiation. To detect betas in the presence of gammas is usually more difficult, but if enough difference exists in their energies, it can be done in this way. In the proportional region, A—and hence the pulse size—will vary rapidly with electrode voltage, and it is necessary to use well-stabilized power supplies or many miniature batteries. If possible, an argon-carbon dioxide or a hydrogen-methane mixture should be used for a fill-gas. Both require less voltage than most other gases and both give stable operation, with good time resolution.

The theory of the operation of Geiger counters is very complex (*9*). A Geiger counter is a proportional counter in which the applied voltage is high enough for the gas multiplication of the initial ions to produce a discharge that spreads along the entire length of the wire. Gas multiplication ceases when the combination of the space charge that is due to the positive ion sheath and the motion of the sheath away from the anode lowers the field below the multiplication threshold. The size of the pulse produced by a counter of this design is independent of the nature of the ionizing event; it is usually great enough to allow recording of the pulse without further amplification. Usually there is a delay averaging a few tenths of a microsecond between the ionizing event and the start of the rise of the Geiger pulse. The pulse ordinarily reaches usable size in a fraction of a microsecond. Pulse length is several microseconds, being determined by the time constant of the amplifier input circuit. The counter is then dead for a period of a few hundred microseconds and then gradually recovers in a period of comparable length. Ionizing events occurring during the dead time cannot be recorded; those occurring during the recovery time are recorded, but as pulses of reduced size.

The common Geiger counter uses a thin wire as an anode and a coaxial metal cylinder as a cathode. The whole arrangement is enclosed in, or forms part of, an airtight chamber that may be evacuated and filled with suitable gases, usually at reduced pressure. The characteristic feature of counters used today is the inclusion of a polyatomic gas as a part of the filling. Numerous filling mixtures have been tried, a common one being 9 parts argon to 1 part ethyl alcohol at a total pressure of 10 cm of mercury. Other polyatomic vapors, such as methane, butane, acetone, xylene, and amyl acetate, may also be used. Counters containing such gases are commonly called "self-quenching"; they might be more accurately termed "non-self-reinitiating." The role of the polyatomic molecules (*8*) is a dual one: to absorb ultraviolet quanta and thus eliminate the possible occurrence of the photoelectric effect

[3] Optimum conversion thickness is given somewhat more accurately by $t = \ln\frac{\mu_e}{\mu_\gamma} \Big/ \mu_e - \mu_\gamma$ where μ_γ is the gamma absorption coefficient, and μ_e is the absorption coefficient of the electrons.

at the cathode, and to prevent secondary electron ejection by positive ions at the cathode. In an argon-ethyl alcohol Geiger counter, the positive ion cloud will contain both kinds of ions. Since the ionization potential of argon is 15.7 ev and that of ethyl alcohol 11.3 ev, in a collision between an argon ion and an alcohol molecule it is energetically possible for the ion to obtain an electron from the organic molecule. It is not possible, however, for the opposite process to occur—an alcohol ion cannot become a neutral molecule while producing an argon ion. Since each ion may make as many as 10^5 collisions in crossing the counter, the ion cloud reaching the cathode will consist entirely of alcohol ions. The ions that approach very close to the cathode surface will pull electrons from the metal and become neutral molecules. Many of these neutral molecules will be in excited states and, were they argon, could emit photons or liberate a secondary electron by an inelastic collision with the counter wall, either of which would reinitiate the discharge. Polyatomic molecules, however, have a lifetime against dissociation that is much shorter than the time required for either of these processes; consequently there is no mechanism by which the discharge can be reinitiated. It is also necessary to consider the excess energy available when an argon ion becomes neutralized in a collision with an alcohol molecule. This excess, 4.4 ev, is radiated as an ultraviolet quantum and might conceivably reach the cathode to produce a photoelectron and a second avalanche. Fortunately, most polyatomic molecules have broad absorption bands in the ultraviolet; hence they absorb the quanta and dissociate.

Since some of the quench gas is dissociated in each discharge, self-quenching counters have a finite life. A normal counter contains on the order of 10^{20} polyatomic molecules, and about 10^{10} of these are "used up" by dissociation at each discharge. The maximum counter life will then be about 10^{10} counts, and counting will probably become erratic after about 10^8. Counters in which the quench gas is not used up have recently been constructed (*10*) by employing very small amounts (0.1 percent) of chlorine, bromine, or iodine. These gases apparently have one excellent property: after they dissociate, they tend to recombine, thus repairing the quench gas for reuse. There is also a drawback: the halogens are all strongly electronegative gases and therefore tend to form negative ions that can reinitiate the discharge, producing spurious counts. Halogen counters, however, have been operated successfully.

Neutrons may be detected in gas counters of all three types with a fair degree of ease. Fast neutrons may be counted by adding some hydrogen to the fill-gas, for they produce recoil protons that initiate ionization. Slow neutrons may be detected by adding a boron-containing gas such as boron trifluoride to the regular fill-gas, or by applying a thin coat of boron to the inner surface of the cylinder. Neutrons react with the B^{10} isotope to produce an alpha particle and Li^7, both of which ionize intensely. Since the cross section for the neutron-B^{10} reaction follows a $1/v$ law, where v is the neutron velocity, slow neutrons are counted much more efficiently than fast ones. It should also be noted that radioactive gases, such as $C^{14}O_2$, can be counted in any type of gas counter by using the active gas as a part or all of the fill-gas.

For counting weak beta samples, such as C^{14} or S^{35}, a windowless flow counter is desirable. This is essentially a shielded Geiger tube into which solid samples are inserted directly, and through which a constant gas flow is maintained to prevent air contamination.

There are many other instruments available for the detection of particles and quanta. These include electroscopes, electrometers, cloud chambers, electron multipliers, scintillation counters, crystal counters, and photographic films. Of these, the last four named are the most frequently employed. Photographic films are widely used in radiographic work of many varieties. They can be manufactured with emulsions that are sensitive to various ranges of radiation intensity and, to some degree, selectively sensitive to different types of radiation. They can be utilized for purposes ranging from the determination of casting flaws and the radiation exposure of personnel to the investigation of the tracks of single particles.

A crystal counter may be made by plating or painting electrodes on the sides of an appropriate crystal and applying a potential difference across the crystal. A pulse is produced when an ionizing particle raises electrons to the crystal's conduction band. Crystals have the advantages over Geiger counters of fast-rising pulses, no delays in pulse formation, a dead time of about 10^{-8} second, small size, and high efficiency for counting energetic quanta. Whether crystals of a given material will count seems to depend upon purity and crystal perfection. Some that have been reported (*13*) suitable for counting are silver chloride, zinc sulfide, diamond, and thallium bromide-thallium iodide. Silver chloride is an easy crystal to obtain commercially, but its counting properties, unfortunately, depend markedly on the way in which it is prepared and handled. Diamond is probably as good a counting crystal as any, and fortunately there is no correlation between counting ability and price.

In another new and very popular counting technique, radiation is allowed to fall on a crystalline phosphor that stops part, at least, of the radiation and passes on a portion of the energy thus obtained in the form of a scintillation of light quanta. This

flash of light, which is of very short duration—about 10 microseconds' decay constant at the very most—is then reflected onto the photosensitive cathode of an electron multiplier tube or photomultiplier. The photomultiplier then transforms the light pulse into an electrical pulse of sufficient amplitude to actuate a scaling unit. The advantages of scintillation counters over Geiger counters are the same as those of crystal counters. Zinc sulfide is generally used as a phosphor for alpha counting, whereas naphthalene, anthracene, and trans-stilbene are good examples of organic phosphors that may be used for beta and gamma detection (*12*). Efficiencies of 20 percent have been reported (*2*) in counting gamma rays of about 1 mev, using naphthalene, in contrast to the usual 0.1–1 percent efficiency of ordinary Geiger counters. Recently the scintillation properties of certain liquids have been under investigation. The most promising solution discovered by the Princeton group (*11*) consists of 0.5 g of terphenyl in 100 ml of *m*-xylene. This solution counted almost as well as a fairly good naphthalene crystal. Recently phenylcyclohexane has been found to be a slightly better solvent (*5*). Applications of liquid scintillation counters with solutions of activities should be forthcoming soon.

The photomultiplier tube most frequently used in scintillation counting is the RCA type 5819. In it one or more photoelectrons from the cathode are multiplied to a readily measurable number by the ejection of more than one (usually 5–8) secondary electrons per incident primary at each of 10 successive anodes. Photomultipliers are sometimes used by themselves for radiation detection, although in most cases efficiency is not high. They also have one very undesirable characteristic—a residual noise or dark current is always present in the output of the tube as a result of leakage across insulators and of thermal emission from the low work function photocathode. This is usually not important in the case of alpha detection and may be eliminated in working with betas and gammas by cooling the tube to liquid air temperature. For scintillation counter work, an even better method is to use 2 photomultipliers in coincidence (*3*). In this arrangement, backgrounds as low as 5 counts per hour are not uncommon.

At present Geiger counters and ionization chambers are the only radiation-sensitive devices that are available in quantity and suitably reliable for commercial application. Since the stability of Geiger counters over long periods of time is frequently questionable, and their life is inherently limited, ionization chambers are usually employed wherever the radiation level is sufficiently intense. Recently some scintillation counters have appeared on the market, and it is expected that they will be increasingly available in the immediate future. Their advantages over Geiger counters are so great that they are preferable for most applications, particularly those in which good geometry is desired.

All the radiation-detecting devices that have been described require some associated electronic circuit in order to present the information obtained in usable form. If an amplifier is necessary to increase signal size, it should reproduce as faithfully as possible the voltage that appears on the collector electrode, but at the level of 10 or more volts necessary to actuate a scaler or discriminator. Several excellent amplifiers have been designed, most of them being based on the Los Alamos model 501 or on the more recent circuit of Jordan and Bell (*4*). Most of these contain discriminators, that is, a bias adjustment at some stage which allows the further amplification of only those pulses that exceed a certain minimum size. In order to keep the input capacity to the amplifier as small as possible, it is customary to mount the first stage or two of the amplifier as close to the counter as possible. For this purpose, special amplifier tubes, called electrometer tubes, especially constructed to reduce grid current, are very useful. Such tubes operate with low electrode voltages so that electrons do not acquire sufficient energy to ionize the residual gas in the tube. In this way grid currents as low as 10^{-15} amp can be easily obtained—a necessity when the current to be measured is of the order of 10^{-14} amp.

Scaling circuits are required to reduce the counting rate of a Geiger counter—for example, from an ordinary value of, say, 3 or 4 thousand counts per second, to a value that a mechanical register can handle, about 50 counts per second. They are all based essentially upon the Eccles-Jordan flip-flop circuit or a multivibrator action, circuits producing one output pulse for two input pulses. Most scalers thus count in powers of 2; they can, however, by appropriate feedback networks, be made to count in powers of 10, thus reducing the effort of extrapolation for untrained personnel.

By adding an integrator circuit with a long time constant, a scaler may be converted easily into a counting rate meter. Such a circuit will show little response to a single pulse but will adjust itself to the average number of pulses received over one time constant. There will thus be a voltage that will vary with the average number of pulses received per unit time; this can be easily measured. It is equally effective and considerably simpler to feed the counter pulses directly to the integrator circuit. The only poor feature of counting rate meters is the fact that they cannot be made conveniently with accuracies of better than about ± 3 percent.

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The Reflecting Microscope[1]

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THE USE OF REFLECTING SYSTEMS of mirror-pairs in microscope objectives extends the range of achromatism of the microscope through the entire optical spectrum—the infrared, visible, ultraviolet, and vacuum ultraviolet regions. This constitutes the most significant advance since the microscope was designed for use in the ultraviolet region by Köhler (*38*) and combined with quantitative spectroscopic techniques by Caspersson (*16*). The reflecting microscope, which historically dates back about three centuries, has been developed in England, Russia, and the United States. Burch (*14*) in 1939 designed a reflecting objective of numerical aperture (N.A.) 0.65 with an aspheric mirror-pair of Schwarzschild (*52*) aplanats, spherically corrected and coma-free. In 1940 Gershgorin, Radchenko, and Brumberg (*13*) extended the system of Maksutov (*43*) and designed a reflecting objective with a spheric mirror-pair and N.A. 0.5. The combination of reflection and refraction was used in objectives designed by Linfoot (*41*) in 1938 and by Johnson (*32*) in 1941. Grey (*28, 29*) in 1949 described a series of microscope objectives of N.A. 0.4 to 1.0 in which Schwarzschild pairs of spheric mirrors are combined with refracting components. Objectives with spheric mirror-pairs have been designed by Seeds and Wilkins and by Kavanagh (*55, 37*). Drew (*22*) has described a solid reflecting objective.

Specifications for various designs of reflecting objectives are given in Table 1. The linear obscuring ratio of numerical aperture has a maximum permissible value of about 0.4 (*23*), beyond which a deterioration of the image may occur. Burch (*15*) has used aspheric mirror-pairs to reduce the fraction of the numerical aperture obstructed by the convex mirror to 0.2 or less and has added a normal-incidence immersion lens, the surface of which is spherical and concentric with the axial object point, to achieve N.A. 0.98. The transmission of all-mirror systems is limited only by the reflectivity of surfaces and extends through the infrared, visible, and ultraviolet regions. The transmission limits of combined reflection and refraction systems are determined by the elements in the refracting component, which include quartz and fluorite.

[1] This work was done in part under a Damon Runyon Senior Clinical Research Fellowship of the American Cancer Society, and was aided by a grant from the National Cancer Institute of the U. S. Public Health Service.

[2] The author wishes to thank C. P. Rhoads for the opportunities and the advice given throughout the pursuit of this work. Indebtedness is acknowledged to the following for the use of experimental models of equipment and for many helpful and enlightening suggestions: V. Z. Williams and R. Scott, of the Perkin-Elmer Corp.; A. J. Kavanagh and H. Weltz, of the American Optical Company; E. R. Blout, E. H. Land, and Mr. Grey, of the Polaroid Corp.; and L. V. Foster, of the Bausch & Lomb Optical Co.

TABLE 1

Examples of Reflecting Objectives

Designer	Type	N.A.	E.F.L.M.N.	O.R.	Made by
Burch (*14, 15*)	A	0.65	3.0	0.2	
	AI	.98	3.0	< 0.2	
Brumberg *et al.* (*18*)	S	.50	6.0		
Grey (*28, 29*)	S	.4	2.4	0.4	BL
	SR	.72	2.8	0.3	BL
Kavanagh (*37*)	S	.56	3.2	0.5	AO
	SI	.85	2.8	< 0.5	AO
Seeds and Wilkins (*55*)	S	0.65	2.6	0.4	RJB

S, spheric, *A*, aspheric mirror systems.
R, refracting, *I*, immersion components.
O.R., linear obscuring ratio of numerical aperture.
BL, Bausch & Lomb Optical Co.; *AO*, American Optical Co.; *RJB*, R. & J. Beck, Ltd.

Optical systems for the application of the reflecting microscope to absorption microspectroscopy in the infrared, visible, ultraviolet and vacuum ultraviolet regions, and to fluorescence and emission microspectroscopy are described herewith.

Instrumentation

I. *Monochromator, reflecting microscope, and radiation detector.* This system (Fig. 1) is used for microscopy and photomicrography: ultraviolet (*12, 39, 40, 47*), visible, fluorescence (*46*), polarized light (*47*), and color translating (*13, 40, 7, 45*), and for microphotometry and absorption microspectroscopy (*42, 47, 46, 54*) in the ultraviolet and the visible regions, with photographic or photoelectric detectors, and in the infrared region with thermal detectors. There are two principal methods, which are the equivalents of Köhler and critical illumination, for illuminating a reflecting microscope with a monochromator. In the usual method (*a*) the prism or the grating of the monochromator is imaged in the plane of the object, the field of the objective but not the aperture may be filled with light as the slit width is decreased, and all portions of the field are illuminated with the same intensity and spectral distribution of light. In the alternative method (*b*) the exit slit of the monochromator is imaged in the plane of the object, the

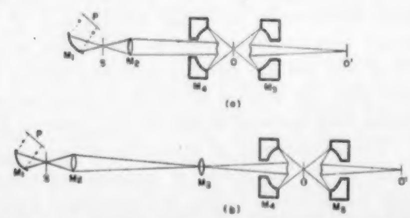


Fig. 1. Achromatic monochromator, reflecting microscope, and detector. Two methods of illumination: (*a*) the grating or prism, *P*, is imaged in the object plane, *O*; (*b*) the exit slit, *S*, is imaged in the object plane, *O*. Suitable detector is placed in the image plane, O^1.

dimensions of the field but not the aperture decrease with the slit width, and there may be variation in the intensity and the spectral distribution of light in the field. Method (*a*) is preferred for microscopy and photomicrography, whereas method (*b*) is useful for absorption microspectroscopy at high spectral resolution. The general equation relating the optics of the microscope and the monochromator is as follows (*42*):

$$\frac{fc}{d_c} + \frac{fo}{d_o} = \frac{d_s}{d_f}\left(1 + \frac{1}{M}\right), \tag{1}$$

where $\frac{fc}{d_c}$ and $\frac{fo}{d_o}$ are, respectively, the aperture numbers (focal lengths divided by linear apertures) of the monochromator collimator and microscope objective, d_s is the monochromator slit width, and d_f and M are, respectively, the field of view and the magnification of the microscope objective.

An example of this system is illustrated in Fig. 2.

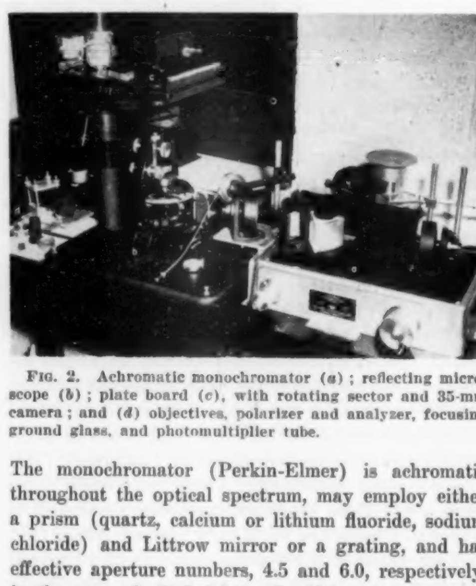


Fig. 2. Achromatic monochromator (*a*); reflecting microscope (*b*); plate board (*c*), with rotating sector and 35-mm camera; and (*d*) objectives, polarizer and analyzer, focusing ground glass, and photomultiplier tube.

The monochromator (Perkin-Elmer) is achromatic throughout the optical spectrum, may employ either a prism (quartz, calcium or lithium fluoride, sodium chloride) and Littrow mirror or a grating, and has effective aperture numbers, 4.5 and 6.0, respectively, in the axes of slit height and width. Accessory reflecting optics designed by Scott (*53*) permit illumination in accordance with method (*b*), Fig. 1. The reflecting microscope has a condenser and objective with N.A. 0.72, aperture number 0.5, and design by Grey (*29*). A rotating step sector is placed at the image plane for plate calibration in photographic photometry (*18*). A photomultiplier tube (RCA 1P28) is used for photoelectric photometry (*8*). Investigations with plane polarized ultraviolet light are carried out with a modified (*1*) Glen-Foucault prism polarizer and analyzer. For color-translating ultraviolet microscopy (*40*) a 35-mm camera is used, which very accurately indexes successive frames. A system for

phase contrast observations in visible light employs an accessory illuminator (Bausch and Lomb) which projects an optical annular diaphragm into the back focal plane of the reflecting condenser.

If the values for the aperture numbers of the monochromator collimator and microscope objective, together with that for the field of view, 0.15 mm, are substituted in equation (1), the slit width, d_c, is found to be 1.8 mm. At 250 mμ the linear dispersion at the exit slit of the monochromator is 2.0 mμ per mm for a fused quartz prism, so that the required band pass is 3.6 mμ. When the microscope is illuminated by method (*b*), Fig. 1, the objective aperture and a useful, although not a complete, field of view are filled with a band pass of 1.2 mμ.

An achromatic monochromator (Bausch and Lomb), especially designed by Foster (*26*) for the illumination of a reflecting microscope in accordance with method (*a*), Fig. 1, has an effective aperture number, 4.4, and a Wadsworth mounting of a 50-mm replica grating, which is blazed for first-order ultraviolet light so that there is a very high efficiency in the region of 230–260 mμ. The linear dispersion in the first order is 6.6 mμ per mm, and the band pass required to fill both field and aperture of the reflecting objective with N.A. 0.72 is 10 mμ.

Recent advances in instrumentation which utilize system (I) include a continuous recording ultraviolet and visible microspectrophotometer designed by Sinsheimer (*56*) under the supervision of Loofbourow and a color-translating ultraviolet microscope designed by Land *et al.* (*40*). The recording spectrophotometer has a hydrogen arc source, a Wadsworth mounted concave grating monochromator, a reflecting microscope, and a photomultiplier tube as a radiation detector. A comparison beam from the monochromator output and the exit beam from the microscope are recombined, after being chopped at different frequencies, and are superimposed on the same aspect of a photomultiplier tube. The signals are amplified and separated, the comparison beam signal is used to control the voltage applied to the photomultiplier tube, and the compensated signal is then sent through a logarithmic amplifier into a recording potentiometer.

The color-translating principle first suggested by Brumberg (*7*) has been utilized in a microscope designed by Land *et al.* (*40*), which makes it possible to use sequentially three different ultraviolet wavelengths and to convert the ultraviolet images so obtained into visible images in three primary additive colors. When these three images are superimposed on a viewing screen a visible image in full color is obtained. The complete instrument includes the following components: a source of ultraviolet radiation; a Wadsworth-type grating monochromator; an automatic exposure control system; a reflecting microscope with optics designed by Grey (*29*); a 35-mm camera; a film-processing station for developing, fixing, and drying 3 adjacent frames in 10–20 seconds; and a triple-beam projector and viewing screen. Other means of ultraviolet image conversion have been considered (*34*) and are under investigation.

II. *Illuminator, reflecting microscope, and spectrograph.* This system (Fig. 3) is used for absorption (*46, 42, 2, 35, 48*) and fluorescence (*46, 48*) microspectrography of cells, solids, and solutions in the ultraviolet, visible and, potentially, the vacuum ultraviolet regions, and for microemission spectrography (*42*). A reflecting condenser focuses the spectrum of the source on the object, and a reflecting objective images the object on the slit of a prism or grating spectrograph. The images are dispersed in the spectrograph and refocused on the photographic plate as a series of discrete or overlapping monochromatic images. A condition that is to be met in order to fill the aperture of the spectrograph with light is as follows (*42*):

FIG. 3. Illuminator, reflecting microscope, and spectrograph, or spectrometer. Reflecting condenser, M_1, focuses spectrum of source on object. Reflecting objective, M_2, images object, O, on slit, S, of spectrograph. Images, O^1, are dispersed by grating or prism, P, and refocused by lens, M_4, on photographic plate. In alternative method, M_5 reimages O^1 at entrance slit, S^1, of spectrometer. For fluorescence spectrography suitable filter is inserted proximal to M_1.

$$\frac{fc}{d_c} \leq \frac{fo}{d_0} \geqq M+1, \tag{2}$$

where $\frac{fc}{d_c}$ and $\frac{fo}{d_0}$ are, respectively, the aperture numbers of the spectrograph collimator and the microscope objective, and M is the objective magnification.

In absorption microspectrography a comparison is made between the photographic density of the spectral images of the source with and without the object imaged in the slit. For fluorescence microspectrography all but the exciting radiations are filtered from the source. Microemission spectroscopy (*42*) requires the use of a simple reflecting objective which images the emission spectra in the slit of the spectrograph.

A working example of the system is illustrated in Fig. 4. The apparatus consists of interchangeable sources of illumination for the region 230–650 mμ (Type AH-4 mercury arc and Hanovia hydrogen arc), as well as an auxiliary visible phase system designed

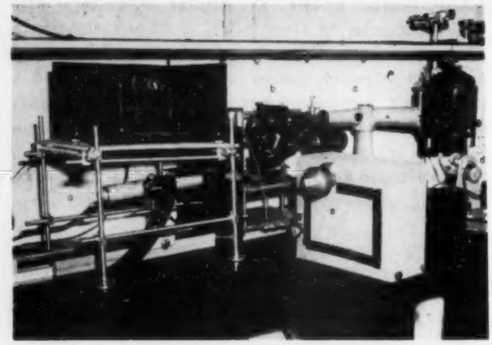


FIG. 4. Illuminator (*a*) with mercury arc above and hydrogen arc below: reflecting microscope (*b*), rotating sector and spectrograph (*c*), logarithmic cam (*d*), and grating monochromator (*e*).

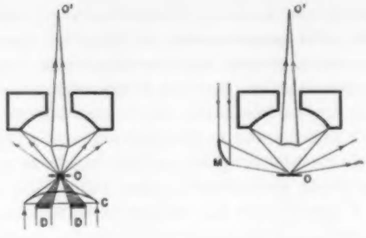
by Kavanagh (*37*); a microscope with a reflecting condenser and objective of N.A. 0.56, aperture number 0.7, and design by Kavanagh (*37*) and a small quartz spectrograph (Hilger) with aperture number 11. It is found from equation (2) that under these conditions the objective magnification required to fill the aperture of the spectrograph with light should not exceed 15. In actual practice the objective magnification is 50, so that less than the full aperture, resolving power, and speed of the spectrograph is utilized. Aside from theoretical considerations the minimum practical slit width employed in absorption spectrography and determined by the sensitivity of the recording material (Kodak Spectrum Analysis No. 1, 103-O-UV, SWR, and Tri X Pan) and by the densitometer scanning beam is 15 μ, which corresponds to a linear dimension of 0.3 μ in the object. A rotating step sector is placed at the entrance slit of the spectrograph for plate calibration (*6*). For the detection of finer detail in the absorption or the fluorescence spectrum the photographic plate can be moved during exposure by means of a logarithmic cam in accordance with the method of Holiday (*31*). In fluorescence spectrography a set of chemical and glass filters (*5, 36*) is used to limit the exciting radiations of the mercury arc to band widths of 15 μ in the ultraviolet region from 245 to 365 mμ.

System (II) has been used by Jope (*35*) and by Barer (*2*) for microabsorption spectrography of the red blood cell, employing reflecting objectives designed by Burch (*15*). Loofbourow (*42*) has made use of the method in microabsorption spectrography of single crystals, thin solid films, and minute quantities of solutions, and in microemission spectrography.

III. *Illuminator, reflecting microscope, monochromator, and radiation detector.* This system has been used in infrared microspectroscopy by Barer, Cole, and Thompson (*3*), by Blout, Bird, and Grey (*4*), and by Gore (*27*) and is indicated in the alternative method of Fig. 3. The spectrum of the infrared source is focused on the object by the reflecting condenser. The image formed by the objective is relayed by the mirror, M_3, to the entrance slit of the monochromator in a single beam recording infrared spectrometer (Perkin-Elmer). Barer, Cole, and Thompson, using reflecting objectives of N.A. 0.65 designed by Burch, obtained infrared spectra over the region of 2–15 μ with objects (crystals, fibers, tissues) that were 20–50 μ in diameter. Blout, Bird, and Grey, using reflecting objectives of N.A. 0.4 designed by Grey (*40*), have recorded infrared spectra of objects as small as 50 μ and compared the spectral data with those obtained for macro-samples of the same material. In a detailed theoretical treatment of the factors involved, it was shown, as can be less rigorously derived from equation (2), that the useful magnification of a microscope objective when associated with a spectrometer is equal to the ratio of the numerical apertures, respectively, of the objective and the spectrometer. A consideration of diffraction theory gave a value of 6 μ as the minimum for two linear dimensions of an object whose spectrum is to be obtained with an ideal infrared microspectrometer having an objective numerical aperture of 1.5, and recording out to wavelength of 15 μ. The minimum value of the third dimension of the object, the sample thickness, is determined by the absorption coefficients and the signal-to-noise ratio of the spectrometer.

A potential hazard in the use of either system (II) or (III) is that the object is exposed to the entire spectral radiation of the source throughout the recording. In order to avoid this an infrared microspectrometer based upon system (I) with an infrared monochromator, followed by a reflecting microscope and a radiation detector, is currently being designed (Perkin-Elmer).

IV. *Reflecting microscope with oblique illumination.* Two methods for the oblique illumination (*17*) of a reflecting microscope (*a*), by transmitted light and (*b*) by reflected light, are given in Fig. 5. An annular diaphragm in (*a*) is placed at the back focal plane of an Abbe-type refracting quartz condenser of N.A. 1.25 and is dimensionally equivalent to the image of the objective aperture at that plane. No direct rays from the condenser enter the objective, because the rays in the central cone are stopped by the convex mirror of the objective, those in the middle of the hollow cone are stopped by the annular diaphragm, and the rays in the outer hollow cone are too oblique. For oblique illumination with reflected light (*b*), the source is imaged onto the plane of the object by a spherical mirror in such a manner that the sum of the



(a) (b)

FIG. 5. Reflecting objective with oblique illumination (dark field): (*a*) by transmitted light from refracting condenser, *C*, fitted with annular diaphragm, *D*; (*b*) by reflected light from spherical mirror, *M*.

angles of incidence and reflection relative to the optic axis exceeds the angular aperture of the objective. When light scattered from the object with unaltered frequency is imaged in the slit of a spectrograph, either Tyndall or Rayleigh scattering occurs, whereas if the frequency is changed, either fluorescence or the Raman effect is operative.

Applications of the Reflecting Microscope

Chemistry and physics. The potential usefulness of the reflecting microscope in systems for absorption microspectroscopy in the infrared, visible, ultraviolet, and vacuum ultraviolet regions lies in the small order of magnitude of the analytic sample. In accordance with diffraction theory the resolving power, *d*, of a microscope is given by

$$d = \frac{1.2\,\lambda}{NA_o + NA_c} = \frac{0.6\,\lambda}{NA_o}, \qquad (3)$$

when NA_o, the numerical aperture of the objective, is the same as that of the condenser, NA_c, and λ is the wavelength. Thus, the theoretical minimum transverse diameter of the analytic sample as set by the resolving power of an objective with N.A. 1.5 and computed from equation (3) is 6 μ (*4*) in the infrared region at λ, 15μ, and 0.1 μ in the ultraviolet region at λ, 0.25 μ. The minimum cross-sectional area of the sample as estimated from the square of the linear resolving power of the microscope may not always be capable of achievement because of other limiting factors, such as the sensitivity of the spectrometer and the absorption coefficient of the sample. For this reason Blout, Bird, and Grey (*4*) have discussed the ultimate performance characteristics of an infrared microspectrometer in terms not of the minimum cross-sectional area of sample but of the smallest volume, a product of the area and thickness, which can be observed with a satisfactory signal-to-noise ratio in the recorded spectrum.

Microabsorption spectra in the infrared region from 2 to 15 μ have been recorded on single crystals, fibers, and particles with minimum cross-sectional diameters of the order of 20 (*3*) by 100 μ (*4*), thickness of 1–100 μ, and mass of the order of 10^{-7} to 10^{-8} g (*3*). The infrared spectra of minute samples of vitamins, antibiotics, hormones, and fibrous proteins mounted on disks of silver or sodium chloride have been studied by Barer, Cole, and Thompson (*3*), by Gore (*27*), and by Blout, Bird, and Grey (*4*). An additional application of the reflecting microscope has been made by Barer, Cole, and Thompson (*3*) in the use of polarized infrared radiation (*20, 24, 33, 44*) for the investigation of the internal structure of single crystals and fibers. These preliminary studies indicate that the reflecting microscope in systems for infrared microspectroscopy will be useful in determining both the presence and the spatial orientation of atomic groupings and will contribute to the understanding of the physical and the chemical structure of organic molecules.

Microabsorption spectra in the ultraviolet region from 230 to 370 mμ have been determined on optically homogeneous samples with cross-sectional diameters of the order of 0.3×1 μ (*46, 48*) to 10×100 μ (*42*), thickness of 1–1000 μ, and mass of the order of 10^{-8}–10^{-10} g (*2*). A sensitive densitometer (Ansco), fitted with a circular aperture of diameter 20–50 μ and used with a high-speed recording potentiometer (Leeds and Northrup), permits a photometric analysis at a slit height of 50 μ, which is equivalent to an object dimension of 1 μ (*46*) in a system of 50 times magnification. Loofbourow (*42*) has recorded the ultraviolet absorption spectra of minute quantities of amino acids, purines, and pyrimidines, either mounted on quartz slides in the form of single crystals and vacuum-evaporated solid films or placed in solution in microcuvettes with capacities of 0.003 ml. Finally, if the ultraviolet light is plane-polarized, information can be obtained concerning the spatial configuration of absorbing groups in relation to the axis of a crystal or a fiber.

Additional applications of the reflecting microscope to physics and chemistry aside from those related to spectrochemical microabsorption analysis include emission and fluorescence microspectroscopy. For microemission spectroscopy, a reflecting objective has been used by Loofbourow (*42*) to form a magnified image of a minute area (166 μ^2) of an iron arc on the entrance slit of a spectrograph. The fluorescence spectra of single crystals of organic compounds in view of the low intensities that are often involved are preferably photographed at magnifications that are just sufficient to fill the spectrograph aperture with light. The relation between the spectral distribution of the energy of excitation and of emission can be studied by simultaneously photographing the absorp-

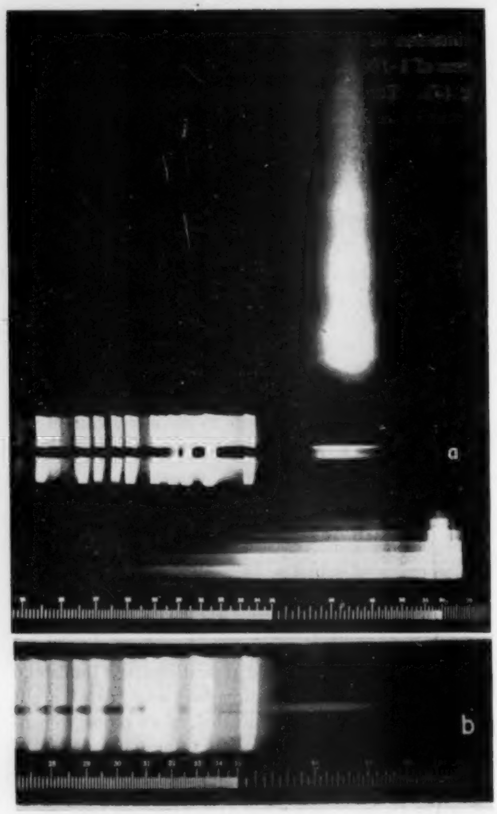


FIG. 6. Fluorescence spectra of (a) 20 μ crystal of β-naphthylamine with stationary and moving plate; and (b) human red blood cell treated with formalin. λ scale, mμ/10.

tion and the fluorescence spectra (Fig. 6). Oblique (dark-field) illumination with transmitted light is in some instances preferred for fluorescence microspectrography and is useful for the investigation of scattered radiations of the Tyndall and the Rayleigh type. A microdensitometric tracing is made of the experimental spectrum, which is photographed on a calibrated plate and compared with a reference spectrum obtained from the directly transmitted radiations of the source. By this means the difference between the relative spectral distribution of the incident and the scattered or the emitted radiations is determined.

Biology and medicine. The reflecting microscope can be used for microscopy in the visible region with bright-, dark-field, phase contrast, and fluorescence illumination and unpolarized or plane-polarized light and in the ultraviolet or infrared region with a suitable means of image-conversion. The methods as outlined by Jones (*34*) for converting an image of one wavelength into an image in another wavelength employ the photographic plate or film, the fluorescent screen, and electronic devices—the image tube, the flying spot scanner, and the image orthicon—developed for use in television. In the ultraviolet region from 0.2 to 0.4 μ and in the infrared region from 0.8 to 1.2 μ, the photographic method has been conventionally used; the infrared image tube (*57*) (1P25, RCA) is useful (*25*) for radiations in the neighborhood of 0.8 μ. A photographic method of image-conversion from the ultraviolet to visible full color has been ingeniously developed by Land *et al.* (*40*).

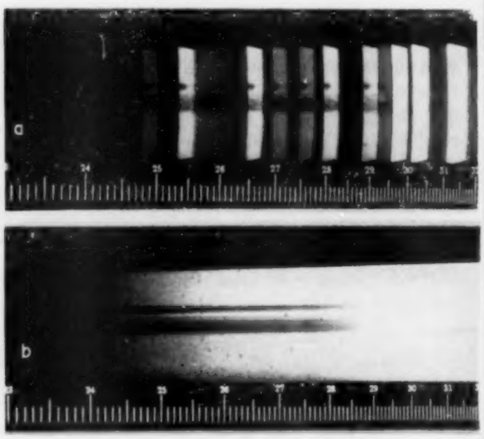
In microscopy, in order to meet the requirements of image contrast and resolution, it is necessary to fulfill the usual conditions of Köhler and Abbe that: (1) the access of the illuminating beam to the condenser be controlled by an aperture diaphragm, (2) the area of illumination in the object plane be limited to the field of view, and (3) the aperture of the condenser and the objective be uniformly filled with light. The peculiarity of design of reflecting microscope optics is such that at the customary position the substage diaphragm is not likely to serve adequately as the sole aperture stop, and stray radiations may pass the central mirror of the condenser and be transmitted directly to the field of view. It is generally desirable, therefore, to illuminate the central mirror with a circular beam of light that is nearly collimated and dimensionally comparable in cross section to the central mirror.

The reflecting microscope may be used in biology and medicine for the observation, and for the physical and chemical analysis, of tissues, cells, and cellular constituents. Analytic systems include microscopy with image-conversion from the invisible to the visible spectrum; absorption microspectroscopy in the vacuum ultraviolet, ultraviolet, visible, and infrared regions with unpolarized and plane-polarized light; and fluorescence microspectroscopy, together with other means of studying the transformation of absorbed radiation.

The natural appearance of the living mammalian cell in ultraviolet light was first photographed with a reflecting microscope and found to contrast with that of an injured or a dead cell (*39*). Microspectroscopic studies (*47*) of single living cells in tissue culture were carried out at a few wavelengths in the ultraviolet region and within limits of exposure that were not injurious. Spectrographic recordings (*48*) of the ultraviolet absorption of living cells were made simultaneously at many wave bands from 240 to 365 mμ, but not without eventual injury to the cell.

When the reflecting microscope is used for the absorption spectrography of a cell in accordance with system (II), the images of the cell in many wave-

lengths of light are brought to focus in the plane of the slit, and the light that passes through the slit is dispersed and focused on the photographic plate. Upon the images of the lines or of the continuum emitted by the source are superimposed the absorption patterns of the cell. The portion of the cell through which the incident light passes in order to gain entrance to the slit is a volume bounded by two parallel planes, *ab* and *cd* in Fig. 7, and by the upper and lower surfaces of the cell. The separation of the two planes is 6 μ for the bright line source and 2 μ for the continuous source. The spectromicrograph obtained in this manner has two components: one in the spectral, or horizontal, axis which relates the light absorption and wavelength for any morphologic component; and the other in the morphologic, or slit height, axis which indicates the absorption of various morphologic constituents at a particular wavelength. In collaboration with G. N. Papanicolaou, this analytic method was used to study fixed and unfixed squamous, parabasal, and abnormal cells of the cervical mucosa designated by Papanicolaou (*49*) as classes III, IV, and V, respectively, with features suggestive of, fairly conclusive for, and conclusive for cancer. The ultraviolet spectromicrographs of portions of these cells cells were recorded and the extinctions $\left(E\lambda = \text{Log}\ \frac{I_o}{I}\right)$ were calculated over the region of 240–350 mμ. Frequency distribution data for the maximum extinctions at 260 mμ in the nuclei of cells are given in Fig. 8. There is both a greater average magnitude and a broader range of values for the extinction in the abnormal cells. Since the optical path length when estimated from the nuclear dimensions was not alone sufficient to account for the differences in the extinctions, and the influence of fixation was not a determining factor—the relative differences were comparable for cells treated with formalin or glycerin—it was concluded that an average increase of both the totality and the density of factors that account for optical opacity had occurred in the abnormal cell.



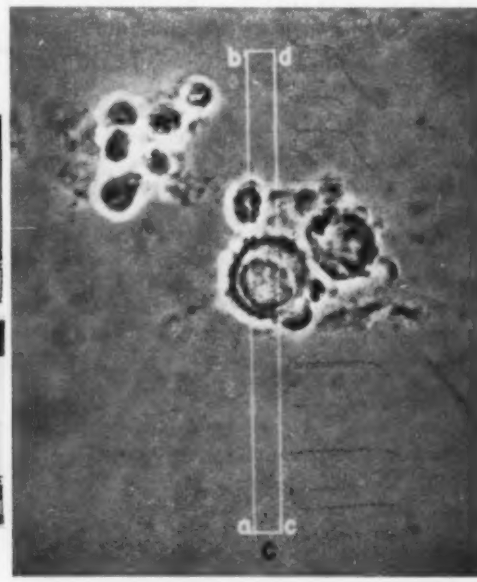


Fig. 7. Spectromicrographs, (*a*) with mercury arc and (*b*) with hydrogen arc, of field indicated in phase photomicrograph (*c*) by the area *abdc*. Class IV cell of cervical smear, formalin-fixed. λ scale, mμ/10.

These observations were then considered from the point of view of developing a quantitative, physical, and ultimately automatic method for scanning and processing smears of cells in clinical oncology. The use of light absorption in a scanning method is precluded by the frequent occurrence of stratification of cells and the summation of effects, whereas with a light-emission method, such as secondary fluorescence photometry, the effects of stratification are not necessarily additive. For this reason, the fluorescence intensities at 365 mμ (Fig. 8 [*b*] were determined for cell nuclei stained with a basic fluorochrome such as berberine sulfate (*30*), under specified conditions (*46*) which limit the dye principally to nuclear structures. It was found that, as the morphologic appearance of the cell became more significantly abnormal, both the average and the range of relative values for the

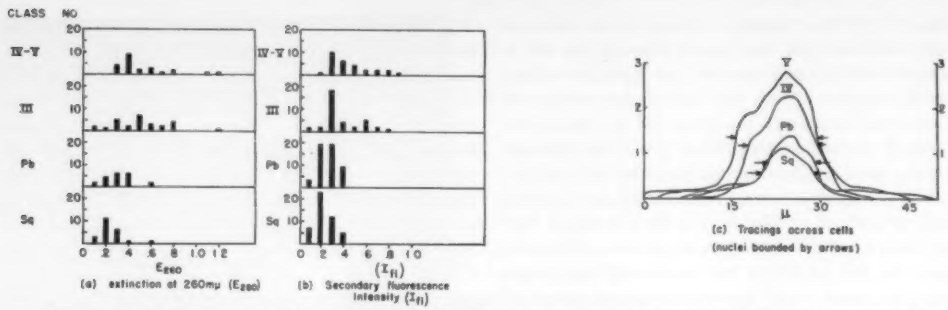


FIG. 8. (*a*) Extinctions at 260 mμ in 0.3μ² areas of nuclei of unstained cells; (*b*) fluorescence intensity of nuclei of cells stained with basic fluorochrome; (*c*) relative absorption at 260 mμ and fluorescence intensities related to positions along cell diameters. *Sq*, squamos; *Pb*, parabasal; *III*, *IV*, and *V*, abnormal cells of Papanicolaou classification in cervical smears, fixed and unfixed.

secondary fluorescence intensities of nuclei increased. Whether this property can be satisfactorily and conveniently utilized in the physical detection of cellular abnormality remains to be seen.

The theoretical limitations in the use of optical methods for the quantitative study of the cell are emphasized by the number of factors (*16, 19, 21, 47, 51*) that influence the absorption of light in cellular material: the amount, the volume of distribution, the spatial orientation, the photochemical reactivity, and the multiplicity of the absorbing material, together with the nonspecific losses of light by scattering and reflection. The complexity of the problem that at first thought appears incapable of solution may be resolved into analyzable components by the use of the reflecting microscope in various or all portions of the optical spectrum. It is hoped that a synthesis of knowledge derived by this and other means will then contribute to a further understanding of the cell in health and disease.

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Amplifying and Intensifying the Fluoroscopic Image by Means of a Scanning X-Ray Tube[1]

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THE X-RAY TUBE OF TODAY represents a considerable improvement over that of Roentgen at the time he discovered x-rays. The development of a detector for the x-ray shadow image has not progressed nearly so far, however, in spite of the fact that techniques that are applicable to this process have been known for some time. The commonest device for the direct observation of an x-ray shadow image is the fluoroscope, which is not fundamentally very different from devices developed before the turn of the century. In a general way, the basic problem is this: to find a means whereby the maximum amount of intelligence as to the structure of an object under observation may be extracted from the x-ray photons that have penetrated it and to create a readable shadow image that may be viewed directly, and that is bright enough and large enough to show the desired detail. Such an ideal system would necessarily reduce the x-ray dosage to an object, which is important especially if it is a living organism.

It was Paul C. Hodges, of the Department of Roentgenology at the University of Chicago, who vividly pointed out to me in a casual conversation the necessity for intensifying the fluoroscopic image without increasing the x-ray dosage to a patient, in particular for the fluoroscopic examination of the human abdominal region. At that time, my thoughts were concerned with the construction of a high-energy electron-Bremsstrahlung scanning microscope, and a search was being conducted for a suitable and fast detector for the Bremsstrahlung. The success that I. Broser and H. Kallman (*1*) had achieved with anthracene for the detection of beta and gamma rays suggested the possibility of inorganic fluorescent crystals as a means for detecting high-energy quanta. A search was made of several inorganic crystals, and a few, such as calcium fluorite, calcium tungstate, and lead barium sulfate, showed extremely promising possibilities. These crystals had high density, a short period of fluorescence—of the order of a fraction of a microsecond—and were transparent to their fluorescent radiation. The realization that such crystals existed immediately pointed to the possibility of a solution to Dr. Hodges' problem.

First, just what is the magnitude of the problem? A photographic film may be used to record a shadow image, although it is rather insensitive and not suitable for direct viewing. After exposure and development, the film is generally observed at a brightness level of some 30 ml, at which brightness level the eye is capable of separating contours of 100 percent contrast spaced .001 inch apart. On the other hand, if a more sensitive fluoroscope is used in observing the human abdomen, the brightness level will be of the order of 100 μml, a level such that an eye well adapted to the dark will just separate 2 contours of 100 percent contrast spaced approximately 2.5 mm apart. There is also another difference. At a brightness level of 30 ml, the difference in contrast that may be detected by the eye is of the order of 1 or 2 percent, whereas at a brightness of 100 μml the difference in contrast level that the eye may detect is of the order of 20–40 per-

[1] This work has been supported in part by grants from the U. S. Public Health Service, the Office of Naval Research, and the industrial sponsors of the Institute of Radiobiology and Biophysics.

[2] The author wishes to express his thanks for the support given to this work by the U. S. Public Health Service and the Office of Naval Research. Stimulating discussions with Paul C. Hodges and Lester S. Skaggs have been very helpful. In addition, Tom O'Donnell and Ed Bartal, of the machine shop, and Henry Katzenstein have been of great assistance in many of the intricate problems in connection with the project.

cent. Thus it would be highly desirable to use a system in which a brightness gain of the order of a million may be obtained, especially if this can be done without introducing any extraneous background, or noise, as it is commonly called (though brightness gains of considerably less than this, of the order of 1,000 times, would represent a considerable improvement, indeed).

ward, since the observer must be in a direct line from the x-ray generator through the object to the fluoroscope, and little can be done to modify the fluoroscopic image obtained.

Two general procedures are available for improving upon this situation. One method consists of forming an image on a fluorescent screen and obtaining a reading by some electrical method; the other consists of

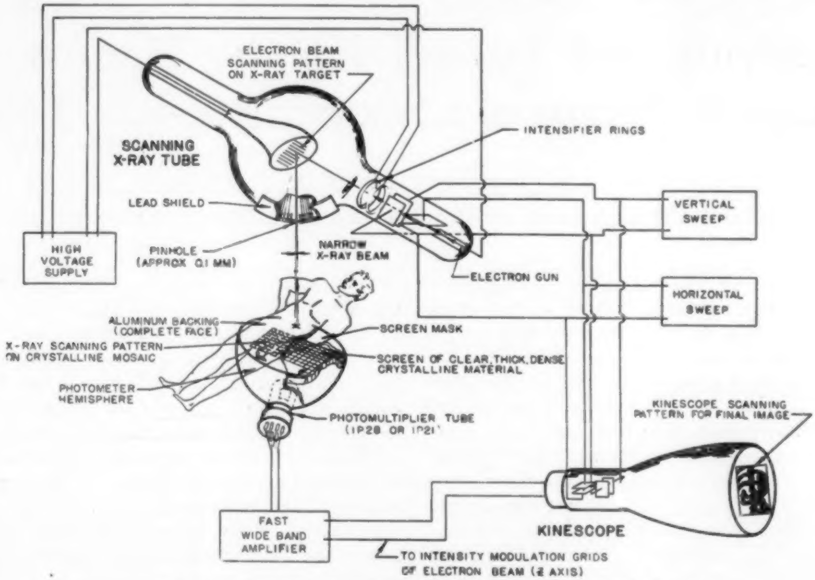

FIG. 1. Scheme for the amplification of the fluoroscopic image.

A question that might legitimately be asked is, Why not increase the brightness by increasing the x-ray intensity? In the case of living organisms, for example, if the abdomen of a man is under observation, it is found that the patient receives some 50–70 r in a fluoroscopic examination of the gastrointestinal tract. This dose is a rather sizable fraction of the mean lethal dose of x-rays for total body radiation; consequently, this means of increasing the brightness of the fluoroscopic image for such an observation is eliminated. On the other hand, if inanimate objects are observed, then the main difficulty lies in the dosage that may be received by the observer, either directly or indirectly. Though higher intensities may be used, a considerable hazard from leakage is presented to the observer. Further, if it is desired to make an examination of a rather thick object, then more penetrating x-radiation must be used. If, however, an image is to be formed on the fluorescent screen, it must be thin; and, if it is thin, it will not completely absorb the x-rays, and the information will be inefficiently extracted. In general, a fluoroscope is awk-

irradiating the patient from point to point, converting the x-ray intensity into electrical impulses, and then assembling the image at some later stage. The first method has the disadvantage that a sharp image must be formed on a fluorescent screen immediately after the object; hence there is an inherent limitation as to the thickness of the detector that may be used. One particular method that has been tried is to view the fluorescent screen with an image orthicon, but this is not very satisfactory because the sensitivity of the image orthicon is too low. Another method, which shows considerable promise, has been worked out by Coltman (*2*), in which an image converter tube is employed in a rather simple fashion to increase the brightness some 500-fold.

Consideration of the second method shows that, with suitable fluorescent crystals, it is possible to extract information efficiently from x-ray quanta that have passed through the object at any one point at a given instant. It is also clear that, though x-rays may be scattered in the object, the majority of them may be utilized to yield information as to the penetrability

of the object for a particular position of the x-ray beam. Similarly, the scattering of x-rays in the fluorescent detector is unimportant because, when the final image is reconstructed, all this information will be assembled at one point only, a point that corresponds to the instantaneous position of the beam at the time. A further advantage is that, when the fluorescent screen is viewed by a photocell, and the fluorescent bursts of visible or near-visible light quanta are converted into current pulses, these impulses may then be modified or selected electronically in ways to produce other desired results. The scanning x-ray tube and its related equipment, such as have been developed at the University of Chicago (*3, 4*), offer an example of this method.

Fig. 1 shows a schematic sketch of a rather simplified system of this sort. A finely focused electron beam scans a rather large target in exactly the same fashion as electronic scanning of a kinescope in television. The x-ray tube is enclosed in a lead housing, and the x-rays can only escape from it through a very tiny pinhole; and, since the point of generation of the x-rays is moving and the pinhole is fixed, a scanning beam of x-rays is thus generated. If the system has axial symmetry about a line joining the pinhole and the midpoint of the target, then at a distance from the pinhole equal to the target-to-pinhole distance an inverted scanning raster of x-rays of the same size as that of the target will be formed. The x-rays now fall upon a fluorescent crystal, such as a single crystal of calcium fluorite, whereupon an x-ray quantum is multiplied many thousandfold into visible or near-visible quanta. If an object is placed between the pinhole and the fluorescent crystal, the x-ray beam is modulated in accordance with the structure of the object. The fluorescent crystal is then viewed with a photomultiplier tube, and current pulses of extremely short duration (of the order of 2×10^{-8} seconds) are produced. These current pulses are then amplified, after which they are acted upon by a pulse height discriminator so as to receive only those pulses above a certain magnitude and, thereafter, to limit all pulses to a certain definite value. This stripper amplifier generates pulses that correspond to the number of x-rays that pass through the object at a given point at a given instant. These pulses are then integrated to modulate the electron beam in a kinescope. The electron beam in the kinescope and the electron beam in the target are driven by the same timer; consequently, an x-ray shadow image is constructed on the kinescope of the object under observation. This briefly, then, is the system.

It is of prime importance to consider the quality of the image such a system can produce. First, the resolution is a function of the statistical fluctuation produced in the x-ray shadow image of the object because of the quantum nature of the radiation. The efficiency of generation of x-rays may be approximately given by the equation

$$\text{Efficiency} = VZ \times 10^{-9}, \qquad (1)$$

where V equals the tube voltage and Z equals the atomic number of the target. If n_e electrons in the electron beam of voltage V strike the target and generate x-ray quanta with an average energy of E electron volts, then the total x-ray flux, ϕ_c, will be

$$\phi_c = \frac{n_e V^2 Z \times 10^{-9}}{E} \frac{\text{quanta}}{\text{second}}. \qquad (2)$$

For an electron beam current of 100 ma, which yields 6×10^{17} electrons per second, and with a tungsten target and a tube voltage of 100,000 v, an x-ray flux of 10^{16} x-ray quanta per second is generated at the target. Though this is indeed a rather large number of quanta, it must be remembered that very few of these quanta will ever escape through the pinhole. For example, with a pinhole .001 cm² and 30 cm from the target, approximately 10^9 quanta will emerge per second, or a total energy of 30 μw in the above example. It is interesting to compare this with the ordinary broadcast band for radio. A receiver intercepting a square meter of radiant flux from a broadcasting station 300 km distant, which is radiating 1,000 w of radiant energy at 1 megacycle (the radiant quanta will have an energy of 4.11×10^{-6} ev), will receive 5×10^{16} quanta per second, or somewhat more than was generated at the target from the x-ray tube, and will pick up a total amount of energy from the broadcast station of .003 μw. Thus, quantum-wise, the radio receiver has many more quanta with which to work but, energy-wise, it has far less.

Thus the flux, ϕ_e, through the aperture will be

$$\phi_e = \phi_c \left(\frac{a^2}{4\pi r_1^2}\right), \qquad (3)$$

where a^2 is the area of the pinhole and r_1 is the distance of the pinhole from the target. The pinhole acts as a virtual origin for the x-rays, and the x-rays spread out into a cone, the size of which is determined by the target raster size. The x-rays are further attenuated upon passing through the object that is to be viewed and, if the object is biological tissue, the attenuation will be due primarily to Compton scattering and absorption. Consequently, the x-ray flux, ϕ_g, which remains to impinge upon the detector will be as follows:

$$\phi_g = \phi_e(e^{-\tau x} = \frac{n_e V^2 Z \times 10^{-9}}{E} \left(\frac{a^2}{4\pi r_1^2}\right) (e^{-\tau x}), \qquad (4)$$

where the object of thickness, x, has an absorption coefficient,

$$\tau = (\sigma_a + \sigma_s)\rho$$

where ρ equals the number of electrons per cubic centi-

meter in the material, σ_a is that part of the attenuation coefficient which results in the production of Compton recoil electrons, and σ_s equals that part which yields elastic scattering of x-ray photons. If the object consists of 25 cm of wet tissue, then τ has an average value of .16 reciprocal cm for x-ray quanta that are emitted in the above example when the tube voltage is 100,000 v. Consequently,

$$\phi_g = \phi_e \times e^{-4}, \frac{\phi_g}{\phi_e} = .018,$$

which is an attenuation approximately 50 to 1. Thus the 10^{16} x-ray quanta that were generated at the target have now been reduced to approximately 2×10^7 x-ray quanta per second after passing through the pinhole and then the object, and if it is desired to have a million picture elements per second available for the formation of the picture, this leaves something of the order of 20 quanta per picture element. This small number of quanta places a limitation upon the resolution due to the statistical variation in this number. Of course, the statistical fluctuation may be reduced if the motion of the object under observation is sufficiently slow that the number of quanta in a given picture element may be integrated over several frames. Integration over 6 frames at a frame rate of 30 frames per second would not be objectionable to the eye, for this is of the order of the integration time of the eye; but, needless to say, it is not this that places an upper limit on the time of integration.

The second limitation on definition is due to that of the beam size in the object plane. If the raster on the target is represented by the rectangle with the dimensions α_1 and α_2, which is separated from the pinhole by a distance r_1, the pinhole being rectangular with the dimensions a_1 and a_2, the distance from the pinhole to the object plane being r_2, and the raster at the object plane being rectangular and of the dimensions R_1 and R_2, on which the x-ray beam forms a picture element of the dimensions d_1 and d_2, the following relations are clear:

$$d_1 = \left(\frac{r_1 + r_2}{r_1}\right) a_1 = (1 + M) a_1,$$
$$d_2 = \left(\frac{r_1 + r_2}{r_1}\right) a_2 = (1 + M) a_2, \tag{6}$$

where M is the ratio of r_2 to r_1. Also

$$R_1 = \left(\frac{r_2}{r_1}\right) \alpha_1 - \left(\frac{r_1 + r_2}{r_1}\right) a_1 = M(\alpha_1 + a_1) + a_1$$
$$R_2 = M(\alpha_2 + a_2) + a_2. \tag{7}$$

Since a_1 is considerably less than α_1,

$$R_1 \approx M\alpha_1. \tag{8}$$

For the sake of simplicity, we may assume that all the elements are squares instead of rectangles and drop the subscripts. Now, if Q^2 is defined as the number of picture elements per frame, or Q is the number of lines per frame, then $Q = \frac{R}{d}$. It is desirable to investigate the condition for constant x-ray flux through an object screen of fixed dimensions with a fixed resolution, namely, R and d fixed, which also fixes Q, and then to see how other variables may be adjusted, such as a, α, and M, in order to determine what effect the changes of these variables will have. Substituting values of R and d for Q, the equation is obtained where

$$Q = \frac{M\alpha}{(1 + M)a} = \frac{M\alpha}{d}. \tag{9}$$

Thus, if the quantity Qd is fixed, the variables M and α must be varied accordingly; i.e., if M is increased, α must be decreased. As a typical example, let us consider the case of an object plane to be viewed of 10×10 cm in which the moving spot is $.5 \times .5$ mm at the back of an object 20 cm thick of wet tissue. The front of the object is 25 cm from the aperture, a, and the aperture, a, is 10 cm from the target. Thus M is equal to 4.5, and Q is equal to 200 lines. This immediately fixes α at a value of 2.22 cm and a at 1/11 mm, or 90 μ. Thus, this will produce a picture of rather high quality, somewhat greater than that of a television picture with 160 lines, if sufficient quanta are available. Let us see what this would yield in a tube operating at 125 kv, 100 ma with a tungsten target, which would produce x-ray quanta with an average energy of approximately 62,500 ev. Thus

$$\begin{aligned}\phi_g &= \left(\frac{n_e V^2 Z \times 10^{-9}}{E}\right)\left(\frac{a^2}{4\pi r_1^2}\right)(e^{-\tau x})\\ &= (1.11 \times 10^{16})(6.57 \times 10^{-8})(2 \times 10^{-2})\\ &= 14.6 \times 10^6 \text{ quanta per second.}\end{aligned} \tag{10}$$

Now since Q is equal to 200, the number of picture elements per second will equal $Q^2 f$, where f is the number of frames per second and, in this particular example, will be equal to 1.2×10^{-6} picture elements per second. Thus it is seen that $\frac{\phi_g}{Q^2 f}$ equals approximately 12 quanta per picture element. Though the resolution was satisfactory in this case from the standpoint of the width of the x-ray beam, the statistical fluctuation due to the few number of quanta will be large. However, if this is viewed with the eye, which has an integrating period of its own of approximately 1/5 second, then each picture element will appear to contain approximately 72 quanta. Or, again, advantage may be taken of a slow phosphor from the screen of the kinescope for integrating purposes but, still better, the use of a storage tube that would integrate over any desired number of frames. This would yield a proportional increase in the number of quanta per picture element during the integra-

tion time, but of necessity the observation of motion would be impaired.

Modifications may be made of the above example. For example, Q may be changed to 100 and a changed to 180 μ. Then there would be 48 quanta per picture element, but the resolving power would be reduced to 1 mm. Or, on the other hand, if a is made equal to 1.1 cm and a unchanged and Q unchanged, R will be reduced to 5 cm and the geometrical resolving power will remain unchanged, but there will now be 48 quanta per picture element. By this means one could first locate the position that was to be observed with the larger field, namely, 10 × 10 cm, and then reduce the sweep voltage such that the raster is one-half as large linearly as in the last case, but with a fourfold improvement in the number of quanta per picture element, and the smaller area, 5 × 5 cm, could be examined more closely.

Though the two limitations (briefly, the geometrical and physical) on the picture quality are not independent, they are inversely related by their common factor and thus will exhibit optimum values. Equation (10) may be rewritten thus:

where

$$\phi_g = \frac{Ka^2}{r_1^2} \tag{11}$$

$$K = \frac{n_c V^2 Z \times 10^{-9}(e^{-\tau x})}{E(4\pi)}.$$

If D_v is defined as the flux density of x-ray photons in the object plane, then

$$D_v = \frac{\phi_g}{R^2} = \frac{Ka^2}{r_1^2 R^2} \tag{12}$$

The contrast ratio is defined as $c = \dfrac{\Delta n}{n}$ where n equals the number of x-ray quanta utilized to define a picture element. From statistical considerations, $\Delta n = \beta\sqrt{n}$ where β is a somewhat controversial proportionality constant which, in physical experiments, is usually taken as having a value of one, but may be less, although some are inclined to assign a value of greater than one if the human eye is involved in deciphering the picture element. Thus the contrast ratio becomes

$c = \dfrac{\beta}{\sqrt{n}}$ or

$$c = \frac{\beta}{\sqrt{d_p^2 D_v t}}$$

or

$$d_p = \frac{\beta}{c\sqrt{D_v t}}, \tag{13}$$

which upon substitution of equation (12) yields

$$d_p = \frac{\beta r_1 R}{ca\sqrt{Kt}}, \tag{14}$$

where d_p is the line width due to the statistical fluctuation arising from the quantum nature of the x-rays, and t is the duration of the observation of a picture element. Equation (6) may be rewritten to yield an expression for the geometrical line width, d_g, with S equal to $r_1 + r_2$. Thus

$$d_g = \left(\frac{S}{r_1}\right) a. \tag{15}$$

As mentioned earlier, the nature of these two line widths is such that there is an optimum value for each, and this occurs when the contribution to the line width by each factor is equal, that is, $d_p = d_g$, which yields the following equation for the optimum value of the system parameters:

$$\frac{a}{r_1} = \left(\frac{R}{S}\right)^{1/2} \left(\frac{\beta}{c}\right)^{1/2} \left(\frac{1}{Kt}\right)^{1/4} \tag{16}$$

or in terms of d_g

$$t\left(\frac{c}{\beta}\right)^2 = (RS)^2 \frac{1}{(d_g)^4} \frac{1}{K} \tag{16a}$$

Thus, if the aperture, a, is reduced in size, the size of the scanned field should be reduced to obtain optimum results in proportion to the square root of the size of the raster in order to obtain the optimum results. What is of particular interest is the optimum value of the integrating time for a given contrast ratio, i.e., the quantity $t\left(\dfrac{c}{\beta}\right)^2$

The detectors that have been employed so far have been of a rather low efficiency. This has been primarily due to the fact that the fluorescent emission spectra of the fluorescent materials have been in the ultraviolet around 3,000 A, and the end-window phototube, though it was of an ultraviolet-transmitting glass, absorbed some of the ultraviolet in the semitransparent photocathodes before the light quanta reached the photoelectron-ejecting surface of the photocathode. With calcium fluorite, the conversion of x-ray quanta into current pulses has shown an efficiency of 5 percent when a large detector screen is used. Other phosphors that emit in a more favorable spectral region approach an efficiency of nearly 100 percent in converting the x-ray quanta into usable electrical current pulses. A crystal such as sodium iodide, thallium-activated, yields current pulses proportional to the x-ray quantum that impinged on the crystal, if the crystal is optically clear and all the light generated in the crystal is conducted to the photocathode. With such a crystal, then, it is possible to expose the object to a continuum of x-rays and to observe it as it would appear under any monochromatic band of x-rays, which can be determined by the setting of a pulse height discriminator. This device should be particularly useful for improving contrast, especially where an absorption edge of a structure in the object falls within the wavelength range of x-rays that impinge upon the object.

The current pulses produced by the photocell can

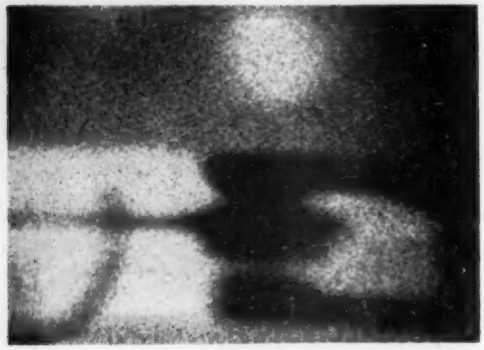

Fig. 2.

be modified in several ways in order to produce certain desirable results. The use of a pulse height discriminator, which converts the detector into a spectrometer, has just been mentioned. If a stripper amplifier is used, the noise pulses may be rejected and a picture may be constructed entirely based on the numbers of x-ray quanta that succeed in passing through the object at any one instant at a particular position. This picture would differ from the regular fluorescent screen picture which yields a shadow image based essentiallv upon the x-ray energy that penetrates the object. Further, if a wide band distributed amplifier is used, then the number of current pulses per microsecond may be integrated over that interval to yield a steady value for that period. Work is now in progress to develop a fast integrating system for this method.

The present low power system now in use in the laboratory works rather satisfactorily with thin objects up to a thickness of 4 or 5 cm of water. Fig. 2 is a picture taken of the image on the kinescope of an object that has been rather overstudied by this particular system. The object is the contact area of a microswitch through which the degrees of contrast caused by the various thicknesses of bakelite are clearly visible, as well as details of the toggle action and the contacts. Motion of the contact mechanism was readily observable on the fast kinescope screen, though the slow kinescope screen with the P7 phosphor gave the appearance that the contacts were moving in molasses. If a sensitive fluorescent screen, such as the Patterson B screen, is placed behind the microswitch and the image observed with an eye well adapted to the dark, no detail at all is discernible in the extremely faint dull image. However, an image is readily seen on the kinescope, and a photometric measurement of the brightness of the two screens reveals a gain of brightness of the order of 100,000 to a million. This is with a tube voltage of 60 kv and a tube current of 3 ma. It is also interesting to note that the Patterson B screen will reduce the intensity of the final image only by a small amount when it is placed in the path of the x-rays between the object and the detector, though a crystal of calcium fluorite of a thickness employed for the detector is completely

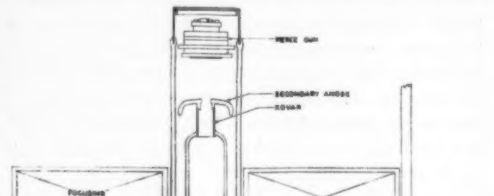

Fig. 3. Scanning x-ray tube.

black to the x-rays. Single objects, such as a strand of wire, are clearly outlined when the wire is of the order of magnitude of the pinhole diameter; single objects smaller than this can be detected though the image is not sharp. It is interesting to note that scattering material placed between the pinhole and the object, or between the object and the detector, produces images of the same quality.

Fig. 3 shows an experimental model of a high-powered tube for use with thick objects of 20–25 cm of wet tissue. This tube employs a water-cooled anode of tungsten and a Pierce-type electron gun. It is hoped to produce a focal spot between 25 and 100 μ in diameter at 125 kv at a current of 100 ma. This tube when used in conjunction with an object of 25 cm thickness of wet tissue will have a value of $K = 1.8 \times 10^{12} \dfrac{\text{quanta}}{\text{second unit solid angle}}$, and, when the

object plane is 50 cm from the target and an area of 10×10 cm is viewed with a resolution of 0.5 mm, then the optimum value of $t\left(\frac{c}{\beta}\right)^2$ is approximately 2 ms. This means that with a contrast ratio of 0.1 (β taken as one, as is customary in physical measurements) the optimum integrating time, t, is equal to 0.2 second, which is the approximate integrating time of the eye.

There are other uses for the scanning x-ray system than that of intensifying the fluoroscopic image. It may be used to study the decay of fluorescence by employing the crystal that is to be studied as the detector screen for the photomultiplier tube, and viewing a small slit or aperture as the object. Since the writing time per line is of the order of 60 µs, then any fluorescence that lasts long compared to a fraction of a microsecond will appear to distort the image in the direction of scanning. In its present form the instrument serves as a low-power microscope with a magnification of some 10 diameters. With pinholes of a few microns in diameter, however, and a triple coincidence photocell circuit, the photomultiplier tube noise can be reduced to a negligible value, and, with the small number of photons that emerge through such a small hole, an image can be constructed if sufficiently long integrating time is used. Higher magnifications may be achieved in this way. Other uses include means for the production of short time pulses of x-rays, either singly or repetitively, and a means of a rocking type of Laue experiment for tiny crystals, wherein the crystal is held fixed and the source moves.

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The Relations between Symbolic Logic and Large-Scale Calculating Machines[1]

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SCIENTISTS IN MOST FIELDS are becoming familiar with the large-scale calculating machines—the so-called mechanical brains—that have made possible the solution of many mathematical problems hitherto considered insoluble. Only a relatively few scientists, however, understand symbolic logic. It is off the main path. What is it? And why is it important in relation to mechanical brains?

Symbolic Logic

Symbolic logic, in its broadest sense, is a new science that has the following characteristics:

(*a*) It studies mainly nonnumerical relations.

(*b*) It seeks precise meanings and necessary conclusions.

(*c*) Its chief instrument is efficient symbols.

Its closest cousin among the sciences is mathematics. But symbolic logic differs from mathematics; to make the differences clear, mathematics and symbolic logic may be compared in a number of respects.

Mathematics deals with words like *plus, minus, times, divided by.* Symbolic logic deals with more basic words like *yes, no, and, or, not, the, of, is, same, different, some, all, none.* Mathematics deals mainly with numbers and their properties. Symbolic logic deals mainly with statements, classes, and relations. Mathematics concentrates on answers to questions like: "How much?" "How many?" "How far?" "How long?" Symbolic logic deals with questions like: "What does this mean?" "Does this set of statements have conflicts or loopholes?" "What is the basis of this proof?"

An example of a rule in mathematics is, "The reciprocal of the reciprocal of a number is the number itself." An example of a rule in symbolic logic is, "The denial of the denial of a statement is the statement itself."

Historically, symbolic logic is the result of applying the powerful technique of mathematical symbolism to the subject matter of logic.

Content of Symbolic Logic

Many scientists comprehend the content of mathematics. But what is the content of symbolic logic?

[1] Based on an address before the Association for Computing Machinery, April 19, 1949, Oak Ridge, Tenn.

There are four or five fairly well-recognized branches of symbolic logic. One of these is Boolean algebra, the algebra of *and, or, not* and statements (or classes). For example, a rule from Boolean algebra is that "neither *a* nor *b* is the same as not *a* and not *b*." Here *a* and *b* are statements or classes, but not numbers. As a result of work by Claude Shannon, Boolean algebra has proved to be useful in designing and checking electrical circuits using relays or electronic tubes. This application of symbolic logic is important in the design and construction of automatic computers.

Another branch of symbolic logic is the one that deals with the foundations of mathematics. It has studied such questions as these: "What is a number?" "What is a variable?" "What is a mathematical function?" It has answered these questions to a large extent. One of the great books in the history of symbolic logic is *Principia Mathematica,* by Bertrand Russell and A. N. Whitehead (published 1910–13), which aimed to furnish a logical foundation for all of mathematics.

A third branch of symbolic logic is called the algebra of relations. This deals with such concepts as symmetric relations, transitive relations, connected relations, series, etc.

Still another branch deals with what is called the decision problem, i.e., the procedure for deciding that a statement is true or false. Symbolic logicians have investigated the problem of proving statements in any mathematical system. These studies have produced some remarkable results. For example, it can be shown that there are statements in arithmetic, and in other mathematical systems, that can never be decided as true or false. Nevertheless, mechanical brains can be applied to deciding statements that can be decided, in problems that would take years of human labor to decide.

So much for an introduction to symbolic logic. How is it related to large-scale calculating machinery?

Logical Operations in Large-Scale Calculating Machinery

When we use desk calculating machines, we notice the numerical operations in a calculation; but we tend to carry out the logical operations in our heads or on paper and we tend not to notice them. When we begin to use automatic computers that perform calculations in long sequences, we find at once that we must pay attention to nonnumerical reasoning operations, as well as to numerical operations. In fact, we notice a long series of questions, all in the territory of symbolic logic rather than in mathematics. Here are some of them:

1. What is the best way to give a machine instructions or orders?
2. What is a sufficient set of orders to instruct a machine to solve any possible problem?
3. What is the smallest set of orders which still leaves a well-functioning machine? (For example, in the method proposed by John von Neumann for instructing the automatic computer ENIAC, only about 70 orders are needed.)
4. How can machines be constructed to determine almost all their own orders?
5. Machines do elementary arithmetical operations like addition, subtraction, multiplication, division, and reference to a table; but what are elementary logical operations that machines should also do?

The last question can be answered in part. Some of the logical operations that may be found in some mechanical brains, and that need to be built into really versatile automatic computers, are decision, comparison, selection, choice, checking, matching, merging, tabulating, sorting. Additional logical operations, such as implication, exception, denial, are in process of being built into mechanical brains.

As long as we do mathematics using pencil and paper and, perhaps, a desk calculating machine, we can get along moderately well without symbols that express the logical operations. When we start dealing with mechanical brains, we find it helpful to express the logical operations in symbols. With these symbols, we grasp a power that we did not have before. Furthermore, these symbols can often be made to fit into ordinary mathematical language. Then machine routines are no longer half flesh and half fowl; they all take on the same mathematical, logical, symbolic nature.

Symbolic Logic in Expressing the Operation of a Counter Mechanism

As an example of the fusion of mathematics and logic called forth by the requirements of large-scale calculating machinery, let us look into an International Business Machines punched-card tabulator, and consider a counter mechanism that can handle numbers of 6 decimal digits. A tabulator is a machine that either lists the information contained in a series of punched cards, or prints totals derived from them, or does both. Its operation is controlled by a plugboard, an assembly of plugwires (or patchcords) connecting hubs (or terminals), all set in a frame. This wired-up frame expresses the instructions for a problem and is changed from problem to problem.

If we examine the plugboard frame of a tabulator, we find 4 inputs and 1 output for the counter mechanism. The 4 inputs are:

1. A set of 6 hubs, one for each digit, called counter entry, which takes in a 6-digit number *n*.
2. A single hub, called the add hub, which takes in a pulse *p*.
3. A single hub, called the subtract hub, which takes in a pulse *q*.
4. A single hub, called the counter total control hub, which takes in a pulse *r*.

Logically, a pulse can be only 1—the presence of a

pulse—or 0—the absence of a pulse; in the machine, however, the timing of the pulse is also important. The output is a set of 6 hubs, called counter total exit, which puts out a number b.

We can express the operation of the counter mechanism with two simple algebraic equations. Let the number held in the counter at any time be h. Then at any cycle x

$$h_x = h_{x-1}\,(1 - r_{x-1}) + a_x\,(p_x - q_x) + 999999\;p_x q_x,$$

and

$$b_x = h_x r_x.$$

What do these two equations mean? If just p is impulsed, the counter adds a. If just q is impulsed, the counter subtracts a. If both p and q are impulsed, the counter adds 999999. If r is impulsed, the counter total exit reads out the number held in the counter, and the counter is at the same time cleared. Obviously, the mechanism would be more flexible if we could read out the number in the counter mechanism without, necessarily, clearing it. In fact, IBM provides a modified counter mechanism with which this is possible.

Since a, b, and h are variables that can be regular numbers, this department belongs to mathematics. But p, q, and r are variables that can only be 1 or 0, like "yes" or "no," and this department belongs to symbolic logic. Only when we fuse the two departments can we exactly express the operation of the counter mechanism.

Symbolic Logic in Programming

We have not yet gone very far, however, into the application of symbolic logic to mechanical brains. Let us take another and more elaborate example of the uses of symbolic logic in large-scale calculating machinery. Let us take an actual problem, see how it can be programmed in a mechanical brain, and note how questions of logic actually occur. A problem that will require several subroutines is the one of finding the square root of a number using an iterative formula, or one that gives a better result each successive time we apply it. One such formula for square root is

$$x_{n+1} = \tfrac{1}{2}(x_n + Y/x_n),$$

where Y is the number for which we want the square root, and the x's are successive approximations. Each time we apply this formula we get a better approximation to the true square root. We begin by making any kind of rough guess about the square root of the number Y, and we call this first rough guess x_1.

To test the procedure, let us obtain the square root of 67.2. We choose 8 as a first guess, because 8 times 8 is 64, and 9 times 9 is 81, and 67.2 is in between these results. So 8 is our first approximation, x_1. In Round 1, 8 divided into 67.2 gives 8.4. The average of 8 and 8.4 is 8.20. This is x_2, our second approximation. It is correct to 3 figures. In Round 2, 8.20 divided into 67.2 gives 8.195122. The average of this number and 8.20 is 8.197561. This is x_3, our third approximation. It is correct to 6 figures. The result of the next round is 8.1975606125, x_4. This is correct to 11 figures. So we see that, with a reasonable guess and two or three divisions, we can obtain all the accuracy we can ordinarily use.

Good iterative formulas are like this: they approximate the true value quickly, and they are very useful on automatic computers. To perform this problem on a machine we recognize 5 subroutines: the subroutine for reading data from input into storage; for carrying out the formula once; for deciding whether to repeat the formula for another round; for preparing to repeat; and the subroutine for sending the answer from storage to output, and stopping. The third subroutine, deciding whether to repeat, is purely logical.

Mechanical Brain ZAC

Let us imagine and stipulate a simple mechanical brain, or automatic computer (ZAC, the "Z Automatic Computer"), able to do this problem.

ZAC has an input tape, an output tape, and 70 registers for storage ordinarily of 8 decimal digits. ZAC has a computer, and the computer can take in an operation OP on one channel, take in 2 numbers a and b on 2 more channels, and give out the result c on the fourth channel:

$$c = a\ OP\ b.$$

ZAC has a program register, which holds each successive instruction that governs the machine. We can transfer numbers or orders into and out of the program register. Some, but not all, numbers will have meaning as orders to ZAC. The program register regularly holds 5 digits: the first 2 digits will be the number of the order, n; the middle digit will be the kind of the order, k; and the last 2 digits will ordinarily be the number of a register, r. At any cycle, the order, or instruction, n, k, r, stored in the program register tells the machine what it is to do at that cycle.

The kind-of-order numbers, k, we shall suppose, can vary from 0 to 9. Using these 10 numbers, we have sufficient flexibility to tell the machine all that we want it to do in finding square root.

The register numbers r vary from 10 to 79. Registers 10–49 will usually store orders having the same order number as the register number; registers 50–69 will usually store numbers in the calculation; and registers 70–79 will usually store constants.

TABLE 1

FIVE-DIGIT ORDER (STORED IN REGISTERS 10–44)

Subroutine	Number, n	Kind, k	Register, r	Meaning
1. Reading data from input into storage	10	4	50	Input of Y to 50
	11	4	56	Input of x_1 to 56
	12	4	51	Input of ½ to 51
	13	6	19	Go to order 19
2. Carrying out the formula once	19	0	74	*Division* to computer
	20	1	50	Y to computer
	21	2	56	x_n to computer
	22	3	52	Y/x_n to 52
	23	0	71	*Addition* to computer
	24	1	52	Y/x_n to computer
	25	3	53	$x_n + Y/x_n$ to 53
	26	0	73	*Multiplication* to computer
	27	1	53	$x_n + Y/x_n$ to computer
	28	2	51	½ to computer
	29	3	57	$\frac{1}{2}(x_n + Y/x_n) = x_{n+1}$ to 57
	30	6	32	Go to order 32
3. Deciding whether to repeat or not	32	0	75	*Inequality* to computer
	33	1	56	x_n to computer
	34	2	57	x_{n+1} to computer
	35	3	69	$T(x_n \neq x_{n+1})$ to 69
	36	7	38	Go to order 38 if 1 is in 69
	37	6	43	Go to order 43
4. Preparing to repeat	38	0	70	*Transfer* to computer
	39	1	57	Old x_{n+1} to computer, equal new x_n
	40	3	56	New x_n to 56
	41	6	19	Go to order 19
5. Sending answer from storage to output and stopping	43	5	57	x_{n+1} in 57 to output
	44	9	44	Stop

The most interesting of these sets of numbers is the kind-of-orders, k. Every k is followed by an r. This is the meaning:

If k is 0, the machine transfers the operation stored in register r to the computer and goes to the next order numerically.

If k is 1, the machine transfers the number in register r to computer register a and goes to the next order numerically.

If k is 2, the machine transfers the number in register r to computer register b and goes to the next order numerically.

If k is 3, the machine transfers the computer result c to register r and goes to the next order numerically.

If k is 4, the machine transfers the number on the input tape to register r and goes to the next order numerically.

If k is 5, the machine transfers the number in register r to the output tape and goes to the next order numerically.

If k is 6, the machine is instructed to go to order r (obtaining it from register r), instead of (as the machine normally does) going to the next order numerically.

If k is 7, and if the number in register 69 is 1, the machine is instructed to go to order r; if k is 7, and if the number is not 1, the machine goes to the next order numerically.

If k is 8, and if the number in register 69 is 1, the machine is instructed to go to the order number stored in register r; if k is 8, and if the number is not 1, this order tells the machine to go to the next order numerically.

If k is 9, the machine stops.

Some of the register numbers that may follow the kind-of-order $k=0$ are 70, 71, 72, 73, 74, 75. These registers contain signals that set the computer for 6 operations, respectively:

70, transfer,	$c = a$
71, addition,	$c = a + b$
72, subtraction,	$c = a - b$
73, multiplication,	$c = a \cdot b$
74, division,	$c = a \div b$
75, inequality,	$c = T(a \neq b)$

In the last operation, the expression $T(\ldots)$ means "the truth value of . . ." and is equal to 1 if . . . is true, and 0 if . . . is false.

THE PROGRAM FOR SQUARE ROOT

The program for square root using ZAC is shown in Table 1.

The first subroutine consists of orders 10, 11, 12. Here we read out from the input tape into registers of the machine. Then we proceed to order 19.

Subroutine No. 2 is now carried out. In orders 19–29, we cover the division, the addition, and the multiplication required by the iterative formula. Then we go to order 32.

In subroutine No. 3, in orders 32–35, we cover inequality; we test 2 successive approximations to see if they are equal or unequal. If they are unequal, we record a 1 in register 69. (In practice, a difference less than a certain tolerance would be accepted as equality.)

Now we come to a choice of program. Using order 36, we go to order 38 if, and only if, there is a 1 in register 69; in other words, if x_n and x_{n+1} are unequal. If there is a 0 in register 69—in other words, if the last two x's are equal—then we go to the next order, 37, and that routes us to order 43.

In orders 38–40, we remove x_n from the iterative formula, subroutine No. 2, and insert x_{n+1} instead. Then with order 41 we go to subroutine 2, which will now compute the next approximation.

In order 43 we read out the final value of x into the output tape, and with the next order stop the machine.

Thus we see how we can program square root with a machine.

In this program, we have to recognize the operation of inequality: this is logic rather than mathematics. We have to recognize different subroutines: this is logic rather than mathematics. We have to provide for the branching of instructions: this is logic rather than mathematics. We have to provide for the machine's deciding for itself when it will stop using a formula and, instead, give out the answer: this, too, is logic rather than mathematics.

These several examples illustrate some of the relations between symbolic logic and automatic computers. We can anticipate that there will be more and more

fusion between numerical mathematics, on the one hand, and nonnumerical reasoning, or symbolic logic, on the other. Machines that play games, machines that separate true combinations of statements from false combinations, other kinds of information-handling machines where emphasis is on logical competence rather than on mathematical competence, are already in existence. Symbolic logic, large-scale calculating machinery, and mathematics will continue to enrich one another in many significant ways.

The Traveling-Wave Linear Accelerator

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THE STUDY OF NUCLEAR PROCESSES commonly involves the bombardment of one nucleus with one or another of the fundamental particles. In many experiments, particularly early ones, the bombarding particles were those emitted by naturally radioactive substances, whereas in later work artificially accelerated particles have been extensively used. In experiments involving neutrons as the bombarding agent, production is normally a secondary process following the bombardment of a primary target either by a charged particle or by gamma radiation.

Familiar particle accelerators are direct current generators of, for example, the Cockcroft and Walton type, and cyclic accelerating devices typified by the cyclotron and betatron. In the former, particles are accelerated by passing through a single large-voltage gradient, whereas in the latter, energy is imparted to the accelerated particles by causing them to traverse a short intense gradient many times when constrained into an approximately circular path by a very strong magnetic field. For this purpose a large and expensive electromagnet is required.

Among the many electrical devices that have been made practicable by the great advances in radio technique of recent years is a new form of high-energy particle accelerator known as the Traveling-Wave Linear Accelerator. This machine has been fully described elsewhere, but a brief description of its mode of operation is, perhaps, not out of place here.

Electrons are introduced axially into a special form of evacuated radio wave guide, along which electric waves are made to travel so that their phase velocity increases steadily from a speed equal to that of the entering electrons up to nearly that of light. Most of the electrons are then constrained into "bunches" moving in constant phase relationship to the waves and are, therefore, accelerated with them.

In the accelerator recently installed at the Atomic Energy Research Establishment at Harwell in southern England, the final electron energy obtained may be as high as 3.2 mev with a mean current of about 120 μa. The electrons may be extracted from the machine by allowing them to emerge through a thin metal "window" at the end of the accelerating wave guide.

Use of magnetron valve. The radio waves are generated in a magnetron valve, such as was developed for radar use, at a wavelength of 10 cm. They occur in very intense pulses, 2 μs in length, and up to 500 pulses every second may be used. The current of electrons during the pulse is, therefore, of the order of 120 ma. If the large current of electrons from the machine is allowed to strike a heavy metal target, intense bursts of gamma rays are produced, and one use of the machine is to provide heavy doses for irradiation purposes.

This particular machine is, however, installed primarily as a neutron source. The gamma rays are converted into neutrons by photodisintegration in a target of heavy water. Some of the nuclei of the deuterium in the heavy water disintegrate and emit a neutron. Some of the neutrons emerge from the target and are available for experimental purposes. The machine will be used as a neutron source for time-of-flight measurements and, it is hoped, will prove a better source than has hitherto been available.

The linear accelerator is inherently suitable for this use since the neutrons are produced in bursts—corresponding to the pulses of radar waves from the magnetron. By a technique similar to that used for range determination in some radar equipment, it is possible to measure the time—which may vary in practical cases from a few microseconds to a few milliseconds—taken by neutrons to travel over a fixed distance from their origin in the source, to a detector (usually a proportional counter).

Calculating neutron velocity. A series of electronic "gates," opened in succession, allows only neutrons of velocities corresponding to the delay between the

initial neutron pulse from the source and the time of opening of the individual "gate" to be "counted" by the detecting circuits. The neutron velocity—and hence the energy—may then be calculated, and the variation with energy of interaction with the nuclei of various elements may be inferred. For example, by placing substances in the path of the neutrons between source and detector, the extent to which the neutrons are absorbed in that substance may be investigated, over a range of neutron energies.

The results of such experiments are of fundamental importance in the design of nuclear reactors, since the choice of suitable materials (both reacting and structural) is severely limited by their nuclear properties.

Since the process of generating the neutrons in the heavy water target, as well as their absorption in samples, is a statistical process, the arrivals in each "gate" occur in a random manner, and, to achieve an accurate estimate of the rate of arrival (or counting rate), as many as possible must be counted. This means that the maximum possible number of electrons must be produced by the linear accelerator.

In this condition, the accelerator is generating harmful radiation at an intensity many thousands of times higher than is safe for exposure of the human body, and a very thick concrete shelter all around the machine is necessary, with only a small aperture for the emergent neutrons. All the electrical, as well as the vacuum pumping, apparatus is, therefore, remotely controlled from a safe point outside the shelter. Precautions are taken to ensure that no person may enter the shelter during operation or "see" the target from any distance less than that at which the intensity is reduced to a safe value.

The basic design of the accelerator was the work of the Harwell scientific staff, and the technical development and construction were carried out by the Mullard Electronic Research Laboratories, which have also cooperated in the design and manufacture of the detecting and "gating" circuits.

Technical Papers

Preparation of Radioactive Glass Beads

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There are many possible experimental uses for small, intensely radioactive sources that can, for example, be imbedded in living tissue. It occurred to us that approximately point sources might be made by incorporating isotopes of high specific activity into glass beads. It was found possible to prepare such beads containing Y^{91}, a pure β-emitter; Sr^{90}, a pure β-emitter that gives rise to an yttrium daughter (Y^{90}), also a β-emitter; and Ce^{144} which, with its praseodymium daughter (Pr^{144}), emits a more complex spectrum.

Use of a preliminary batch of Y^{91} beads imbedded in regenerating rat liver has been reported (*1*). By cutting microscopic sections through the point occupied by the bead, it was possible to obtain single tissue sections treated by a wide range of radiation dosages that were approximately calculable. Further development of the technique has enabled us to prepare beads with activities of the order of 1–2 mc/mg. Such beads are sufficient to produce a sharply demarcated area of liver necrosis within 48 hr, with the radiation dosage diminishing nearly to zero at the periphery of the organ.

Among possible methods for the production of radioactive beads are: (1) adsorption of the radionuclide onto powdered glass, followed by fusion of small quantities of the material to form beads; (2) incorporation of the radionuclide into the raw materials used in the manufacture of glass; and (3) precipitation of the radionuclide in the presence of powdered glass that can then be fused into beads. It was decided after a number of tracer studies (*2*) that the last method offered the most satisfactory means for the production of very small and highly radioactive beads. This is illustrated in Fig. 1*A* and 1*B*, in which the apparent activity is plotted for randomly chosen beads against weight and diameter cubed.

The method described here deals specifically with the production of beads containing yttrium^{91}, although beads of comparable activity were prepared with Ce^{144} and Sr^{90}, and, except for possible alteration in the chemical procedures, the technique may be applied to other radionuclides.

The solution of Y^{91} was received from the Oak Ridge Laboratory as $Y^{91}Cl_3$ containing 50 mc in 18.8 ml of weak HCl solution. To this solution were added 1 mg of yttrium carrier, 5 mg of powdered micro slide glass, and $Y^{91}(OH)_3$ precipitated by the addition of NH_4OH. In the case of Sr^{90} the carbonate was precipitated. After centrifugation, the supernatant was decanted and the precipitate slurried and partially dried in readiness for fusion into beads. The addition of 1 mg of yttrium carrier under these conditions gave recoveries of 95%–97%.

The amount of powdered glass added to the solution was determined by preliminary studies of the minimum

[1] The authors are indebted to A. S. Tracy for the photographs.

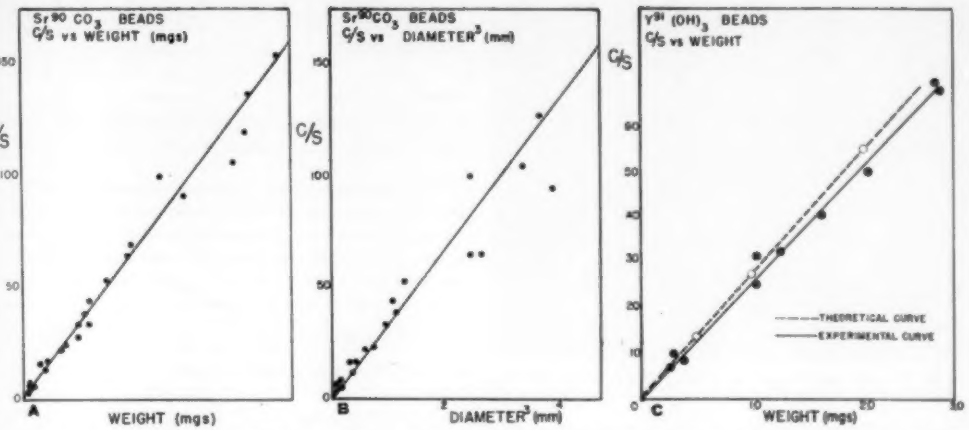

FIG. 1. *A, B*: Apparent activity of randomly selected radioactive glass beads plotted against weight and diameter cubed. *C*: A theoretical and experimental plot of counts per second against weight.

ratio of powdered glass to precipitate necessary to produce translucent and spherical beads. At a ratio of 5:1 (powdered glass to precipitate) relatively good beads were produced, and at the same time the conditions for minimum solids were fulfilled. Ratios of 20:1 will produce somewhat more perfect beads, but the specific activity will be lowered in the same proportion.

After the precipitate is obtained, it is stirred with a 1/16-in. stainless steel rod to mix the powdered glass and $Y^{91}(OH)_3$. The steel rod is also used as a plunger in a small-bore glass tube into which the slurried material is pipetted and dried for 15–20 min under an infrared lamp until it has hardened enough to be extruded in small fragments on a carbon block (about $3 \times 10 \times 15$ mm). The material on the carbon block is divided into smaller portions, the size of which will determine the size of the resulting beads, and then placed in the furnace until fusion of the radioactive beads occurs (20–30 min at 2,000° F). After fusion the carbon block is removed from the furnace and allowed to cool. The beads are then brushed into a glass vial, which is enclosed in a lead container.

The fusion furnace was designed to produce radioactive beads with minimal radiation hazard and to be replaceable at low cost because of the probability of radioactive contamination. It is constructed from a piece of Babcock and Wilcox K-30 insulating fire brick as shown in Fig. 2. The heating element consists of a coil of No. 18 Nichrome V wire composed of five turns wound on a ¼-in. × ½-in. bar stock form. Turns are spaced about ⅛-in. apart. The element is connected to the secondary of a 20-amp, 6.3-v transformer that is controlled through a variable transformer (Variac) for temperature control.

Because a variety of bead shapes and sizes results, a means of proper selection and calibration is necessary. Thus the vial containing the beads is placed in a transparent Lucite box, ½-in. wall thickness, which has a small adjustable opening at the top for remote-control manipulation of special hollow-tipped forceps. This assembly (Fig. 3) is then placed under a microscope, and proper selection of translucent and spherical beads can be made. A calibrated millimeter scale in the ocular piece facilitates measurement of the diameter of the selected beads, which are then stuck on black

FIG. 2. Microfurnace used for fusion of radioactive beads.

FIG. 3. Technique and assembly for selecting radioactive beads.

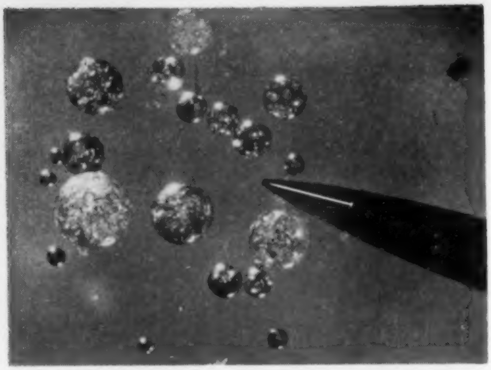

FIG. 4. Random sample of Y^{91}-containing beads and the point of a common pin (magnification $\times 35$).

masking tape and transferred into individual capsules for measurements of radioactivity and for use.

In all these chemical and physical manipulations, radiation hazards must be considered. In most cases the work is done behind lead and/or Lucite shielding with the usual equipment necessary for semiremote-control handling (*3*).

Because of the high activity of the beads, the measurements are made with a Zeus α, β, γ portable ionization chamber that is mounted 10 in. above the measured capsules. The bead measurements are made by relative comparison with a series of Y^{91} standards ranging from 0.1 to 1.5 mc and prepared from a solution whose specific activity was originally determined by calibration against Ra DEF standards from the National Bureau of Standards. With these conditions of measurement, beads have been produced with specific activities ranging from 0.005 mc to 1.5 mc per mg, having diameters ranging from 0.05 mm to 1.0 mm, and weighing up to 1 mg.

The method of determining the radioactivity of the beads leaves some doubt of the validity of their millicurie content; however, under the conditions of measurement, and coupled with the knowledge of the expected theoretical activity of the precipitate (Fig. 1*C*), the error is probably not greater than 30%. The increasing divergence of the experimental curve from the theoretical curve with increasing bead weight might well be attributed to self-absorption.

Fig. 4 is a photograph (magnification $\times 35$) showing a random sample of yttrium beads and the point of a common pin. An actual image of the pin is superimposed upon its enlargement for further comparison. The smaller beads are the ones that are selected for our experimental studies.

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Convenient Method of Mounting Sintered Glass Filters[1]

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The usual method of mounting ultrafine (UF) filters is to fit them by means of a rubber stopper onto a filtering flask with a test tube inside, or onto a test tube with a side arm. Both methods are somewhat cumbersome, and subsequent manipulations—taking the tube from the flask or transferring the filtrate into a test tube by means of a pipette—expose the filtrate to contamination. Besides, the side-arm test tubes are awkward to handle, and the breakage is usually high.

Fisher Scientific Company has put on the market a so-called shockproof condenser coupling (No. 7-702-C) to mount straight condensers for student use. These couplings proved to be very convenient for mounting medium-sized Pyrex sintered glass filters, particularly Corning Glass Company, UF30.

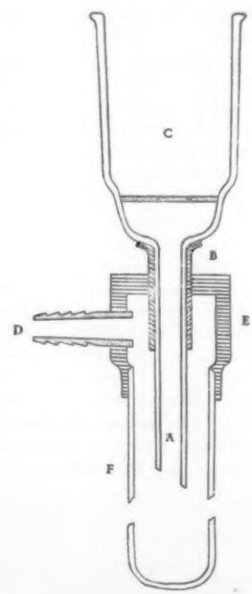

FIG. 1.

Fig. 1 shows how the device is assembled. The stem (*A*) of the UF30 filter is too narrow for the opening of the coupling; therefore a short piece (1 in.) of rubber tubing (*B*) of suitable size (5/16 in. × 3/32 in.) is first fitted on the stem and pushed sufficiently high to spread slightly at the joint of the body and the stem.

[1] This work was supported by a grant from The National Foundation for Infantile Paralysis.

The fitted funnel (*C*) is inserted into the hole of the coupling. The metal side arm (*D*) is plugged with cotton wool, the excess cotton being burned away. The coupling (*E*) now is fitted onto a 1-in. Pyrex test tube (*F*) (different lengths are available). To insure an easy fitting, silicone stopcock grease is used. The top of the funnel is covered with aluminum foil for protection, and the assembly is autoclaved for sterilization.

After filtration, the coupling and funnel are removed, cotton plug from a sterile 1-in. test tube is used to plug the tube containing filtrate, and the funnel is put on the tube from which the plug was removed.

Standard Measures and the Economical Production of Graphs and Figures

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Notes by Gutsell and by Wainerdi, respectively, in SCIENCE (*3*, *4*) emphasize the fact that standardizing of measures has not kept pace with advances in technology, and that the making of graphs continues to be a time-consuming task. This is particularly true of meteorology, where, for example, of the scales of 6 recording instruments, no 2 are alike and 6 different charts are used, whereas, by minor changes in the mechanisms of these instruments, not more than 2 charts would be necessary. The earlier meteorographs (*1*)—necessary for isolated stations and in aerological researches—were assemblies of familiar barographs, thermographs, hygrographs, etc., recording on a single chart, the 3 (or more) records occupying as many sections of the chart, all having separate time arcs and different scales. Accurate evaluation usually was a tedious process. In 1905, for work necessitating rigid economy, I devised meteorographs having a single time arc for all elements and using, for record charts, millimetric cross-section paper. Advantages possessed by this system are small cost, simplicity of operation and—of aerological instruments—small weight, but even the simple records obtained thereby are not always immediately useful, for graphs and copies must be made.

Some years ago, in a bulletin (*2*) prepared for the University of Nevada, records originally in different scales were, for ease of analysis, transposed into a common scale. Instead of the usual process of connecting reference points on coordinate paper, which would have required several weeks of valuable time, I used a form of pantograph with independent coordinates, by means of which graphs in drawing ink, ready for the engraver, were completed in one operation; the entire task was accomplished within a week. This instrument was described at a meeting of the American Meteorological Society in Boston, in December, 1946, but no description has been published.

Fig. 1 is an elevation of the instrument as it is seen by the operator, and **Fig. 2** is a plan. The original figure or diagram, or a blank to receive the graph, may be attached to either cylinder (*A* or *B*) by a Richard spring clamp; or a belt of any desired length, bearing many figures, may be carried on *A* or *B* and over a separate cylinder *C*, which may be placed wherever convenient.

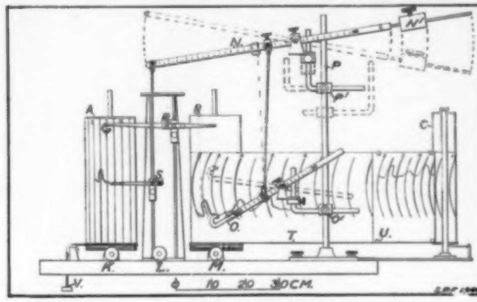


FIG. 1.

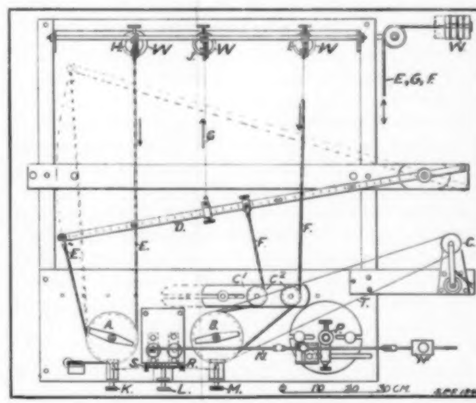
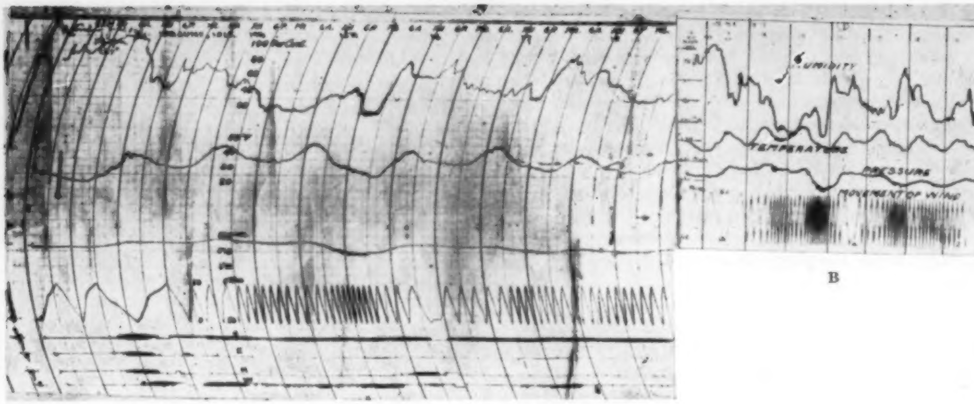


FIG. 2.

Cylinders *A* and *B* are supported frictionally on tubular shafts, to each of which, at its lower end, are fixed a sprocket and a crown gear; one end of a chain *E* or *F*, meshing with the sprocket, is secured to the graduated bar *D*, and the other carries a weight *W*; weights on chains *E* and *W* are balanced by a counterweight on another chain *G*. Obviously, controlled by this mechanism, the scales of these cylinders will vary according to the position of the chain *F* on the bar *D*; as shown, with *F* attached halfway between the axis of *D* and its outer end (carrying *E*), the time scale of *B* will be one-half that of *A*. The same scale for both cylinders is obtained by the use of the same chain over both sprockets. The cylinders are operated by the arbors *K* and *M*, on which, held by friction, are pinions meshing with the crown gears below the cylinders.

When both form and dimensions of a figure are to be duplicated, a stylus or tracer and a pen are attached to the same carrier *R* or *S*, which is clamped adjustably to

[1] Research Fellow (retired).



A B

FIG. 3. Record by meteorograph on Mt. Rose, Nevada. *A*, photograph of original; *B*, a copy by the special pantograph, in one operation for each of the 4 elements: (1) Curved ordinates are changed to rectilinear, (2) Fahrenheit degrees to Absolute, (3) millimeters to millibars, (4) the time scale of 60 mm in 24 hr to 30 mm for the same period; (5) necessary corrections are applied.

a light chain connecting the bar N with the drum L over which it is wound; tension on the chain is maintained by a weight N^1. The stylus is caused to follow the outline of the original figure, and the copy is made simultaneously, in ink, by movements of the cylinders and carrier controlled by milled heads on the drums K or M and L.

When both graph and original figure are in rectilinear coordinates and the scales of the graph must be different from those of the original, the stylus and the pen are attached to separate carriers (R or S), one of which is supported by the bar O suspended adjustably from N. When curved ordinates of an original figure are copied as rectilinear, the stylus is attached directly to O, as shown in Fig. 1, where a diagram, T, is copied.

As indicated by dotted outlines in Fig. 1, the bars N and O can be placed in almost any convenient position on the upright P, and the ratio of movement of one bar to that of the other adjusted accurately. Accuracy of movement of the cylinders is secured by adjustment of the plate C^1 so that chains E and F are parallel between the rollers C^2 and the bar D. Since movements of cylinders and mechanisms are controlled by weights, there are no errors caused by looseness of bearings; backlash between pinions and crown gears is prevented by a separate weight V.

The instrument described occupies a space 1 m square, or about that necessary for a precision pantograph; larger or smaller models of the same accuracy can be produced at approximately the same cost. Paper 40×50 cm, or the belt mentioned (which may be several meters in length), can be used for originals and copies, and graps can be made from values read from text or tables without intermediate plotting on coordinate paper.

The operator of this instrument is comfortably seated facing the recording mechanisms, all adjustments of which are within easy reach, and all movements are controlled by means of two of the milled heads K, L, and M.

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A Miniature Pressure-recording Device

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Air Materiel Command, Dayton, Ohio

The extensive use of intracardiac catheterization for diagnostic purposes and special problems in physiology stimulated the development of a manometer sufficiently small to permit its introduction into the circulatory system. From the theoretical point of view it is advantageous to reduce the dimensions of a manometer. Cutting down the mass of the moving parts actually improves the recording properties by increasing the natural frequency. In most elastic manometers for blood pressure measurements, the greatest part of the effective mass resides in the cannula and its connections. This condition is completely eliminated by putting the recording element at the tip of the instrument. Moreover, such a pressure pickup that is in direct contact with the pressure avoids artifacts due to, and corrections necessary for, the hydrostatic columns in the fluid-filled tubes that connect the circulatory system with commonly used external manometers.

A disadvantage of such a system is the necessity for using an amplifier. Among the various possibilities of constructing such a miniature manometer, the principle of a differential transformer, first outlined by Wetterer (*3*), seemed best suited to give a system having excellent recording properties with a minimum of amplification.

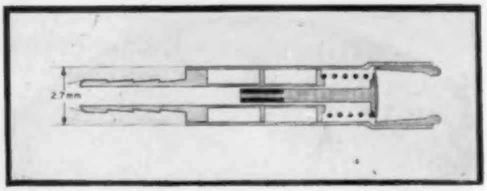

FIG. 1. Miniature manometer. Horizontal hatching, core with two chambers for the transformer coils; vertical hatching, casing; diagonal hatching, ring holding the sealing rubber membrane. Crosshatching, piston; black dots, coil spring; black rectangles, soft iron. Dotted area, catheter. Over-all length of metal tip, 12 mm; largest diameter, 3 mm.

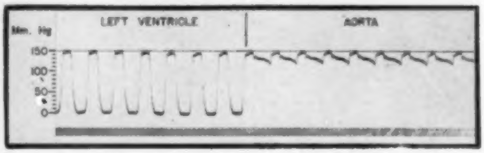

FIG. 2. Pressure record (⅓ scale) taken while catheter was pulled from left ventricle of an intact dog into the aortic root.

After trying numerous designs of pressure-sensitive elements, the authors agreed on one very similar to Wetterer's original, although smaller, sturdier, and simpler to handle. With two years of continuous use and improvement, this manometer has been developed into a rugged and dependable instrument.

The all-metal pickup fits on a No. 8 Cournand catheter. Its construction may be seen in Fig. 1. The movable part is the piston (crosshatching). It consists of a 0.6-mm brass rod carrying on one end a plate of 2.1 mm diameter and on the other end a small piece of soft iron. It is held in position by a steel spring (black dots) and is activated by the pressure on the plate. The steel spring determines the elastic properties of the manometer. A sheet of condom rubber seals the unit. This sealing membrane is easily fixed in place by means of a precisely fitting brass ring (diagonal hatching). The elongation of the casing (vertical hatching) beyond the membrane has a double function. It houses the sealing device and also protects the membrane from direct contact with the walls of the beating heart, which may cause artifacts. The core (horizontal hatching) accommodates the differential transformer. The iron part of the piston acts as an armature. According to its position, it determines the relative coupling of the transformer sections.

This differential transformer is connected to the bridge circuit of a carrier amplifier. A one-knob balancing device permits correction for the capacitance introduced by an extension cord, which may be placed between the amplifier and the pickup. In our experiments a 30-ft extension cord was used. The pickup with the bridge circuit can be incorporated in most commercially available carrier amplifiers with only minor changes, provided these furnish frequencies in the audible range (*ca.* 1,000–15,000 cps) having a reasonably pure sine form. The simple two-stage amplifier especially built for the unit has an oscillator adjusted to 9,000 cps.

The over-all performance of the miniature manometer may be summarized as follows:

1. Natural frequency of 1,000 cps in fluid.
2. Damping ratio, .34.
3. Maximum sensitivity, 50 ma/100 mm Hg.
4. Linear response between −50 and +250 mm Hg.
5. Static calibration is achieved with a mercury manometer by applying suction at the rear end of the catheter. This feature allows calibration of the sterile catheter and control of sensitivity during the measurement without touching the tip or removing the catheter from the vessel.
6. A two-knob amplifier (zero adjustment and sensitivity) provides high stability.

Fig. 2 is an example of a pressure record while the tip of the catheter was pulled from the left ventricle of an intact dog into the aortic root (recording galvanometer Heiland Type C). The record was taken in collaboration with Ellis, Essex, and Wood, of the Mayo Clinic, in tests on the adaptability of the unit for clinical work (*1, 2*).

A modification with the coil spring and sealing device replaced by a corrugated membrane is being tested. Detailed information will be given elsewhere.

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The Use of Thick Paper for Chromatography[1]

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Yanofsky, Wasserman, and Bonner (*1*) have recently described the use of a special heavy grade of filter paper for large-scale paper chromatography. They recommend Schleicher and Schuell filter paper No. 470-A, but state that separation is not as good as on thinner paper. Attempts in this laboratory to apply the procedure to the separation of a mixture of peptides readily confirmed this fact and indicated that for our purpose the separation achievable with this paper was hopelessly inadequate. Essentially, No. 470-A is blotting paper and is highly bibulous. Using secondary butyl alcohol containing formic acid and ethyl formate, about 90% saturated with water,[2] the solvent advances on this paper at the rate of about 17 cm/hr, a rate so rapid that there is little opportunity for selective mobilities to become manifest.

This rate can be greatly retarded by the simple expedient of attaching a strip of Whatman No. 1 paper to one edge of the thick sheet, overlapping 1–2 cm. The two

[1] Aided by a grant from the Commonwealth Fund.

[2] A slight modification of a solvent suggested by Lyman C. Craig, of the Rockefeller Institute.

papers are fastened with a double row of stitches by means of a sewing machine. The material to be separated is applied as a ribbon on the thick paper just beyond the "seam," using the kymograph technic of Yanofsky *et al.* The thin paper is then brought into contact with the solvent, where it acts as a "valve," which allows the requisite slow passage of the solvent along the heavy paper. A strip of thin paper approximately 9 cm in diameter results in a slowing of rate such that 24 hr are required for the solvent to traverse 17 cm of C. S. & S. No. 470-A. Resolution so achieved is superior even to that obtained on Whatman No. 1, and, curiously, it is worth noting that the relative rates of flow are not invariably the same for the two papers with the same solvent.

The rate of flow can be increased by using a narrower strip of light paper, and vice versa. If the ascending method is used, the cylinder of paper must be supported at the top by tying it to a glass or stainless steel support, for the rim of thin paper is not strong enough to support the weight of the heavy paper plus solvent.

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Preparation of Thin Films of Crystalline DDT and γ-Hexachlorocyclohexane in Celloidin[1]

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At this laboratory investigations are in progress to determine the possibility of breeding strains of beneficial insects resistant to DDT and other insecticides; during this work it became necessary to devise a suitable and easily produced test surface. A new method is described here of making thin films of crystalline DDT and γ-hexachlorocyclohexane (benzene hexachloride) rapidly and in large numbers in a celloidin base on glass. As well as being crystalline, these deposits fulfil the requirements of being reasonably uniform and of possessing known quantities in a given area.

Solutions of pure para para DDT (mp > 108° C) or of γ-hexachlorocyclohexane of at least 99% purity (lindane) are made up in a mixture of equal parts of absolute alcohol and ether in which 0.2% celloidin has been dissolved. Insecticide concentrations ranging from 0.3% to 3.0% have been used up to the present. A lantern slide cover glass, size 3¼ in. × 4 in., is thoroughly cleaned with a solvent and lens paper, and a circle 2 in. in diameter is drawn with the aid of a guide in the center of the glass, with a grease china-marking pencil. From a microburette or Mohr pipette 0.15 ml of celloidin-insecticide solution is run into the middle of the cover glass. The solution spreads out rapidly as a very thin film with a circular outline until it is stopped by the grease-penciled circle. Evaporation of the solvents proceeds rapidly; and after about 30 sec or so, determined by trial, the drying

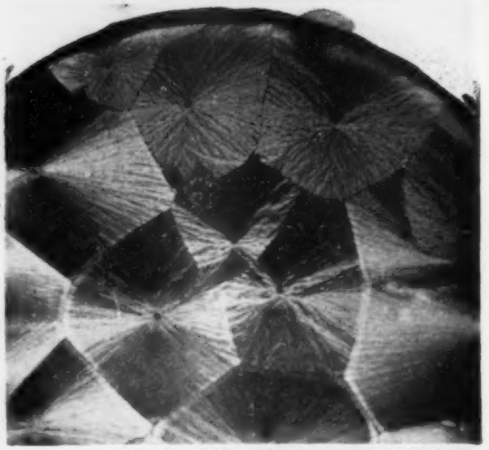

FIG. 1. Part of a crystallized DDT deposit in celloidin, containing approximately 0.08 mg DDT/cm² and showing centers of crystallization (×2).

FIG. 2. Detail of structure of crystals deposited from an alcohol-ether-celloidin solution containing 1% DDT (×120).

[1] Contribution No. 2,669, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Ontario.

film is touched lightly at several points with a needle that has previously been in contact with the insecticide. This seeding induces centers from which a regular branching crystallization proceeds rapidly through the film as it dries. If it dries too rapidly the celloidin hardens before crystallization is complete. This is prevented by covering the films after about 45 sec with a shallow lid, to reduce the rate of evaporation (a flat brass ring 2 in. in diameter and a second cover glass are convenient). The

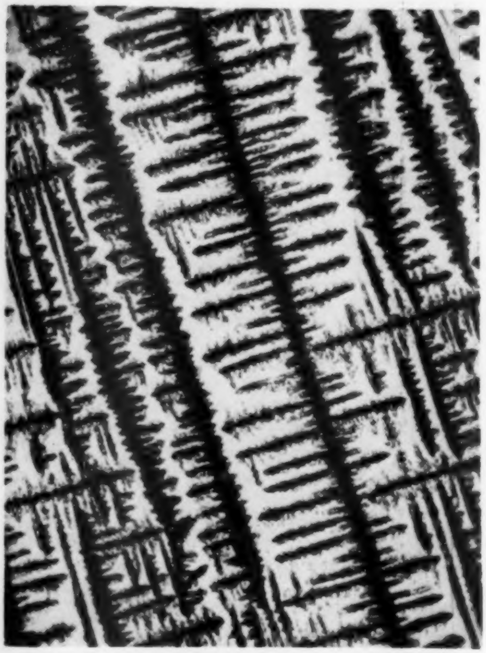

FIG. 3. Detail of structure of crystals deposited from a 1% solution of γ-hexachlorocyclohexane ($\times$120).

celloidin base is estimated to be approximately 0.15 μ thick when dry. A small proportion of films have to be discarded because of irregular or unevenly spaced crystallization. Less seeding is needed in γ-hexachlorocyclohexane than in DDT; and less is needed in the higher concentrations of either, crystallization being more rapid and spontaneous. When crystallization is complete and the celloidin hardened, the cover glasses may be stacked up for a time until needed; a standard 5 in. × 3 in. card index drawer equipped with slotted racks is convenient for storage. The films of DDT are more persistent than those of γ-hexachlorocyclohexane.

The general appearance of part of the DDT deposit showing the centers from which crystallization radiates is shown in Fig. 1. Fig. 2 shows detail of DDT crystal structure under magnification, and Fig. 3 that of the more angular deposit of γ-hexachlorocyclohexane. Fig. 4 shows a simple test chamber convenient for use with *Drosophila melanogaster* Meig. The chamber is made by clipping two cover glass films face to face, separated by a brass ring 3/16 in. thick and of internal diameter equal to the deposit circle. Such rings may be made by sawing off pieces 3/16 in. long from standard heavy-gauge brass pipe of suitable size.

FIG. 4. Test chamber made by clipping two cover glass films face to face, separated by a brass spacer ring.

Anesthetized insects are introduced into the chamber and exposed for varying periods of time. They may be anesthetized again for removal by slipping a strip of paper impregnated with ether between the ring and the upper cover glass, the glass being first moved a little to one side so that the deposit is off center and the ether strip does not touch it. The data obtained are susceptible to the usual probit analysis treatment. The great convenience of the method lies in the rapidity with which films can be made and in the large number of tests that can be carried out simultaneously.

X-Radiation from Electron Microscopes

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We have had occasion recently to monitor our electron microscope for x-radiation while taking motion pictures of electron microscope images (*3*). The survey was necessary from a health standpoint because the microscope was being operated under abnormal conditions, which were optimum not only for the motion-picture techniques but also for the production of x-rays. Following the published work of Silverman *et al.* (*2*) on the same subject, the results of the survey may be of interest and are reported here along with the data of surveys conducted on 3 Detroit instruments operating under normal conditions.

The abnormal conditions for motion-picture work are: (1) the final viewing screen is tilted at an angle of about 30 degrees, and (2) the usual 25-mil condenser aperture is opened to 50 mils. Thus, a more intense beam is al-

lowed to strike an inclined target with a corresponding increase in x-ray hazard. Some remarkably high dosage rates were recorded for these circumstances. Fig. 1

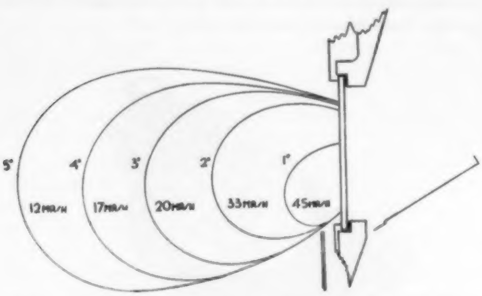

FIG. 1. X-ray isodose curves from an EMU electron microscope at the location of the final viewing screen, the microscope set up for motion-picture studies.

shows rough isodose curves at the final viewing screen. The distances were measured from the microscope window to the unshielded, nylon window of the meter, and since the meter consisted of a chamber 8 in. long, the isodose curves may extend as much as 4 in. farther out than shown. If an individual spent 2 hr with his eye at the 45 mr/hr position while focusing, he would be close to exceeding the formerly recommended maximum of 0.1 r per day. There would be danger of superficial erythema, especially to the eyes, which are prone to develop cataracts under low-voltage x-radiation. Lead glass can be used as an effective shield, or ¼-in. plate glass will interpose 2 half-value layers to reduce the radiation considerably for motion-picture work.

Hillier (*1*) has recommended that the x-ray level be measured and guarded against whenever the nature of electron microscopic work involves the use of a condenser aperture greater than is supplied with the original instrument. This observation is supported by the present work.

A Tracerlab "Cutie-Pie" portable survey meter, which is an ionization chamber of an integrating type, was used for taking the measurements. When the readings were taken the meter was assumed to be bathed with radiation. Table 1 gives values of the dosage from the

TABLE 1

Instrument	Location of dosage	Maximum dosage (varying condenser aperture) (mr/hr)	"Normal" dosage (mr/hr)	Specimen holder present
Edsel B. Ford	Top port	10	10	
Institute, 50-mil	Intermediate screen	65	24	Yes
condenser aper-	" "	230		No
ture: gun	Final screen	40	10	Yes
saturated	" "	40		No
at 500 μa				

microscope when it is set up for motion-picture studies. The dosage is measured at points directly in front of, and 3 in. from, an EMU microscope. The instrument in the "normal" operating condition means, with a saturated, biased source, no objective aperture, condenser current set so that one square in the specimen screen is illuminated, and the final magnification × 5,000.

We have not found that dangerous overdosages may be received from microscopes operated under so-called normal conditions with the usual 25-mil condenser aperture and an untilted final screen. To check this and to offer a suitable comparison with Silverman's report, 2 microscopes in addition to our own have been surveyed in the vicinity of our laboratory (Table 2). The data are

TABLE 2

Instrument	Location of dosage	Maximum dosage (mr/hr)	"Normal" dosage (mr/hr)	Specimen holder present
Henry Ford	Top port	0	0	
Hospital, gun	Intermediate screen	13.5	11.0	Yes
saturated	" "	45.0		No
at 200 μa	Final screen	2.5	1.0	Yes
	" "	4.0		No
General Motors	Top port	0	0	
Research, gun	Intermediate screen	3.5		Yes
saturated	" "	22.0	6	No
at 350 μa	Final screen	2.5		Yes
	" "	5.0	1.0	No
Edsel B. Ford	Top port	10.0	10	
Institute, gun	Intermediate screen	17.0	7.5	Yes
saturated	" "	65.0		No
at 500 μa	Final screen	7.5	0	Yes
	" "	10.0		No

taken again under the same conditions as in Table 1, except that the screen is not tilted and a 25-mil condenser aperture is used. In Table 2 it is seen that for the instruments operated in a normal fashion the dosages are low, and, unless an operator remained for unusually long periods or was constantly closer than 3 in., he would be well within tolerance limits. However, since normal operation is likely to be defined in a variety of ways, because there are so many variables in a measurement of this sort and because tolerance limits are being subject to constant revision, it is recommended that instruments be monitored by individual laboratories.

Maximum dosages are given in the table, which are maximum only for the conditions cited, namely, for variations in condenser current. Dangerous maximum dosages are recorded, but the conditions giving rise to them are usually transient in the microscope, and it is doubtful that personnel would receive daily doses above tolerance from them. A specimen holder (without a specimen screen) reduces the dosage considerably, and in all cases it seems that the *dosage from the intermediate screen* is that to be most guarded against. This may be made negligible by discarding the angled screen and using one

that presents a flat surface to the incident beam. Further protection can be secured at the intermediate level by use of the magnetic shielding provided.

X-radiation from the top port, which might have been expected to be the most intense, is apparently eliminated by supplying the microscopes with lead glass. The intermediate and final levels do not seem to be so much protected in these 3 microscopes. The x-radiation from the top port can also be minimized by discarding the angled screen.

References

1. Hillier, J., and Ellis, S. G. *J. appl. Phys.*, 1949, **20**, 700.
2. Silverman, L. B., Elliott, S. B., and Greenfield, M. A. *Science*, 1949, **110**, 376.
3. Watson, J. H. L., and Preuss, L. E. *J. appl. Phys.*, Sept., 1950.

A Low-Temperature Incubator

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Occasionally the need arises for an accurate and versatile low-temperature incubator or BOD box, but the purchase of a commercial unit is not always justified. In this laboratory a large incubator operating at 28° C and containing 4 fluorescent light fixtures was required for the incubation of microbiological assay tubes of *Euglena gracilis*. Commercial BOD boxes available at that time did not have adequate usable incubating space to serve this purpose, but a standard household refrigerator was easily converted into a large-capacity, low-temperature incubator.

The conversion was accomplished by building and inserting on the top full-width shelf of the refrigerator the unit shown schematically in Fig. 1. Dimensions have been omitted, since actual construction details depend upon size and position of shelves and freezing unit in the refrigerator being converted. This conversion unit effects the isolation of the cooling coils of the refrigerator from the rest of the box, and, by means of controls, the desired temperature of the remainder of the box can be maintained. No mechanical modifications of the refrigerator are necessary, the unit is easily removed to allow normal use of the refrigerator, and the refrigeration mechanism is not put under any strain. The necessary materials, a sensitive thermoregulator and a relay, a coil heater, a fan, and various other items, are readily obtainable.

The freezing unit is isolated from the rest of the box with rigid insulation board (¾-in. Celotex sheathing) partitions. The edges of the insulation boards are edged with rubber weatherstripping to form a snug seal at the back wall, side wall, top, and door of the refrigerator.

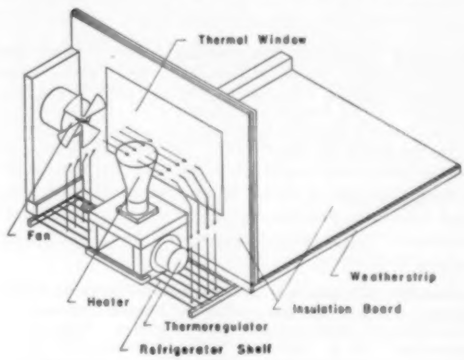

Fig. 1.

The isolated freezing unit is thus allowed to operate normally, and the amount of "cold" transferred to the rest of the box can be controlled by means of a "thermal window," a sheet of metal fitted into an opening in the vertical insulation board next to the freezer. This window acts as the cooling surface for the air in the rest of the box and is made large enough to transfer more heat than is produced by the fan motor and other heat sources.

The temperature of the circulating air is then adjusted by a heater coil that is actuated by a thermoregulator assembly. The heater and thermoregulator are placed, as indicated, on a support that also serves to force the seal of the unit to the side walls, and to direct the flow of air. The fan is attached to a wooden support that also reinforces the partitions, and is placed so that by its direction of rotation it draws air up from the box, forcing it past the thermal window and heater, and down into the box again (Fig. 1). The sensitive bimetallic end of the thermoregulator is placed below the fan so that it is affected by the air coming up from the box. The relay control box is placed outside the refrigerator. Necessary electrical wiring to the fan, heater, and thermoregulator is passed between the box and the rubber insulation of the door.

With the refrigerator operating at a temperature colder than is necessary, the thermoregulator can be adjusted to maintain the desired temperature in the box. Temperatures ranging from 7° to 40° C can be maintained, with no greater variation than ± 1° C throughout the incubating space.

Book Reviews

Analytical Absorption Spectroscopy: Absorptimetry and Colorimetry. M. G. Mellon, Ed. New York: John Wiley; London: Chapman & Hall, 1950. 618 pp. $9.00.

In the words of the editor, "The present volume on absorptimetry and colorimetry has been written almost entirely from the viewpoint of what seems of most practical concern in a modern chemical testing and analytical laboratory." The nine chapters with their contributing authors include:

"Chemistry: Preparation of Systems for Absorptimetric Measurement," M. L. Moss; "Physics: General Principles of Absorptimetric Measurements," M. G. Mellon; "Color Comparimeters," W. B. Fortune; "Filter Photometers," R. H. Muller; "Spectrophotometers: Ultraviolet and Visible Regions," K. S. Gibson; "Photographic Methods," E. R. Holliday; "Applications of Ultraviolet and Visual Spectrophotometric Data," E. I. Stearns; "Spectrophotometers: Infrared Region," L. J. Brady; and "Measurement and Specification of Color," Deane B. Judd.

The reader will find that, in general, the discussions are limited to applications of the methods with little more than a brief introduction to the underlying theories. Ample references are given, however, if it is necessary to obtain information in greater detail than is justified in a general reference book of this type. Of special importance to the analytical chemist is the careful consideration given to the sources of errors that may be encountered and the proper means for minimizing their effects on analytical results.

Another indication that the authors had the welfare of the analytical chemists at heart is the attention given to the standardization of nomenclature. Workers in the field can appreciate the task involved in compiling a book of this type when the situation is one which may be described as virtually a state of anarchy, with each worker steadfastly adhering to his own code. Throughout all this the analyst has been but a voice crying in the wilderness. It is hoped that he may derive some comfort from the care with which the nomenclature has been handled here. Even so, one complete chapter is based on another system (chapter 6).

Obviously, one may expect considerable overlapping in subject matter from chapter to chapter when each is written by a different author, but it is sufficiently extensive in this case to suggest that more care could have been exercised in the editing. As a case in point, there is little reason that one should find a more complete description of filters in the chapter on spectrometers than he finds in the chapter on filter photometers. The net result, then, is that each chapter is more or less complete unto itself which, after all, may be of some advantage.

For the most part, the volume is up to date, with references as recent as 1949, and the subject matter is, on the whole, well presented. It is regrettable, however, that more recent information is not included in the chapter on infrared spectroscopy. For example, one is disappointed to find that the discussion on nondispersive analyzers is limited to the negative filter type, with no mention of the later use of pneumatic detectors. Similarly, the Golay infrared detector, which has met favor with many workers, has been neglected. The discussion of techniques involved in applications of the method might also have been developed more thoroughly.

Although these and other minor shortcomings may be found, the various aspects of the field have been well summarized. This is especially true of the chapters on chemistry, spectrophotometers (VS and UV), spectrophotometric data, and the measurement and specification of color. It is also gratifying to find that the photographic method has not been overlooked and that its usage has been ably covered. For these reasons, the analyst will find this to be a useful reference book on the application of absorption spectroscopy.

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Das Polarisationsmikroskop als Messinstrument in Biologie und Medizin. Hans H. Pfeiffer. Braunschweig, Germany: Friedr. Vieweg, 1949. 94 pp. DM 8.50.

Chemische Spektralanalyse, Vol. I. 4th ed. Wolfgang Seith and Konrad Ruthardt. Berlin, Germany: Springer-Verlag, 1949. 173 pp. DM 16.50.

The polarizing microscope, long an indispensable instrument for petrographic research, has become of increasing importance in other fields of science. The present brief monograph was written to acquaint biologists with qualitative and quantitative methods of polarizing microscopy as employed in the study of biological objects. In the restricted space of 94 pages the author gives a competent treatment of the subject which, as he sees it, will become of steadily increasing importance.

After a discussion of fundamental concepts and definitions and of the different types of birefringence, especially those produced by oriented submicroscopic elements, the construction and operation of the polarizing microscope are described in some detail. The second chapter, representing methodology, deals with the preparation of biological samples for measurements with polarized light. The third chapter contains metronomic details regarding quantitative measurements and the use of different types of compensators for the exact determination of phase differences.

This handy little volume may be of great value for biologists who want to obtain reliable information in this field.

In *Chemische Spektralanalyse* the authors' purpose is to give chemistry students or industrial chemists sufficient information for handling spectrographic equipment and auxiliary apparatus and to familiarize them with the most important methods of qualitative and quantitative spectroscopic analysis. This goal is reached by detailed discussion of about thirty typical laboratory experiments. Clear drawings and photographic reproductions facilitate easy understanding.

The treatment is confined to methods and equipment developed and used in Germany. The authors are aware of this deficiency and intend to include discussions of the progress of English and American research in the next edition. Indeed, this would greatly increase the value of this manual and would automatically bring the treatment of grating spectrographs into the scope of the text. The fact that the book came out in its fourth edition is sufficient proof of its usefulness for instructing students at German universities. Instructors in spectrography at American universities may also profit from the study of this book, which is written in a clear and easy German.

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Industrial Instrumentation. Donald P. Eckman. New York: Wiley; London: Chapman & Hall, 1950. 396 pp. $5.00.

As the author states in his preface this is an introduction to the science of measurement rather than to the detailed study of the mechanism to accomplish the measurement. A single volume with a thorough coverage of instrument types is quite welcome. Illustrative of this coverage is the chapter on mechanical measurements, which includes displacement gauges, strain gauges, force meters, velocimeters, and accelerometers. We can find in this book electrical, mechanical, and pneumatic measuring means for measuring pressure or differential pressure, as well as such diverse instruments as the mass spectrometer and the polar planimeter. The large number of illustrations, all of which are schematic, add materially to the written word.

The book collects in one volume practically all the conventional methods for the measurement of physical phenomena. Many of these are in general industrial use today, but others find application only in research and testing laboratories. In that the laboratory instruments of today will become the industrial instruments of tomorrow, this volume should be of interest to all industial instrument engineers. The chapter on "Methods for Composition Analysis" is indicative of this fact, for it will introduce to many readers new measurement methods based on well-known physical phenomena. The author has often departed from instrument methods to delve into the fundamental physics pertaining to the particular measuring problem. These departures extend from the entire first chapter on "Qualities of Measurement" to the next to the last chapter on "Flow Metering." *Industrial Instrumentation* should be a welcome addition to the schools and colleges that have or are adding courses in industrial instrumentation and control. The problems included in each chapter will extend the book's usefulness in classroom work. Many of these require an analytical approach through fundamental physics before the answer can be determined. An appendix of 23 tables is of added interest to both the student and the instrument engineer. The author has done an excellent job in presenting the many means for measuring physical phenomena. As a companion volume to Eckman's first book, *Principles of Industrial Process Control*, it is a continuation of the author's clear presentation of the fundamentals involved.

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Metallurgical Applications of the Electron Microscope. London, England: Institute of Metals, 1950. 164 pp. $3.50.

This volume consists of 14 papers presented at a symposium organized by the Institute of Metals and held at the Royal Institution, London, on November 16, 1949. The purpose of the symposium was to draw together workers from all parts of the world to review and discuss the present state of the field of electron microscopy as applied to metallurgy. Among the countries represented were England, France, United States, Belgium, and Germany.

Since the volume comprises the separate papers presented at the symposium, there is some repetition, particularly in the introductory discussion of electron microscopy. The arrangement of the book places the more general papers concerned with instruments and associated techniques at the beginning, followed by those dealing with specific problems and applications.

The subject matter will be of interest primarily to those actively engaged in the electron microscopy of solid surfaces. The standard replication techniques and variations thereof are quite fully treated and the results obtained by them compared and criticized. The applications of interest to metallurgists include brasses and bronzes, steels, aluminum alloys, and nickel-chromium alloys. Precipitation and age-hardening problems represent the bulk of the applications, although the etching of pure aluminum, studies of slip lines, fracture, and metal powders are also presented. The papers are all well illustrated with high-quality reproductions of electron micrographs.

The concluding General Discussion should be of considerable interest, with its pertinent questions concerning replicas and their interpretation and the recognition of etching reactions as a little-understood phenomenon. One or two short contributions not included in the symposium proper are found in the discussion.

It is hoped that such symposia will be held in the future and that the subject matter will be published in as effective a manner as was this one.

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Biophysical Research Methods. Fred M. Uber, Ed. New York-London: Interscience, 1950. 667 pp. $9.50.

In the seventeenth century theoretical medicine developed along two pathways, the iatromathematical, and the iatrochemical, the former school regarding physiological processes as consequences of the laws of physics, the latter assigning chemical explanations to vital phenomena. Although not your *Compleat Iatromathematician*, the present publication, comprising contributions from a diversity of laboratories, both here and abroad, effectively covers modern basic areas of operation:

Avoid Fruitless Experiments, F. M. Uber; Osmotic Pressure Measurements, D. R. Briggs; Centrifugation, E. G. Pickels; Viscosity Measurements, L. V. Heilbrunn; Temperature Determinations, L. R. Prouty and J. D. Hardy; Calorimetric Measurements, M. Kleiber; Quick-Freezing and the Freezing-Drying Process, E. W. Flosdorf; Bioelectric Measurements, H. J. Curtis; Electrophoresis, D. R. Briggs; Ultrasonic Vibrations, E. C. Gregg, Jr.; When to Use Special Microscopes, O. W. Richards; Electron Microscopy, J. Hillier; Action Spectra and Absorption Spectra, H. F. Blum; X-Rays and X-Irradiation, J. W. Gowen; Electrons, Neutrons, and Alpha Particles, L. H. Gray; Stable Isotopes as Tracers, F. M. Uber; and Radioactive Tracers, A. F. Voigt.

In general there is a combination of theoretical and practical considerations of some of the most useful techniques of modern biophysics. Much of the information is standard and readily available in existing texts, whereas other portions deal with relatively recent developments, e.g., thermistors. The book represents a convenient grouping of a number of methods for a brief but comprehensive survey, with about 31 percent of the volume devoted to x-rays, nuclear physics, and isotopes. There is a subject but not an author index, and each chapter gives adequate references to earlier literature, in many cases arranged under distinctive headings.

A refreshing down-to-earth initial chapter by the editor, on "How to Avoid Fruitless Experiments," is enlivened by several homey cartoons. These considerations are of general value not only in biophysics, but in any science. Expanded into a formal course of lectures, they would be useful to the graduate student embarking on his career. The chapter could well have been amplified into a survey of the techniques of recording observations, indexing notebooks, making calculations, plotting results, checking one's work, and efficiently presenting data in tabular form.

Brief statements or tables of typical values for biological fluids or living cells would have been enlightening in certain instances, but the reader can remedy some of these omissions by reference to *Tabulae Biologicae*. The chapter on centrifugation devotes itself exhaustively to the use of centrifuges for determination of sedimentation constants of materials in solution. No reference is made to such applications as determinations of surface forces of, and interfacial tensions within, living cells or separation of groups of cells from heterogeneous mixtures. The evaluation of the ingenious centrifuge microscope in chapter 4 strikes this reviewer as captious, in view of the results obtained with it and recorded in the literature. Moreover, the facile generalization (p. 128) "that the correlations between protoplasmic activity and viscosity appear to be much more satisfactory than any correlations between such activity and respiration" is at least debatable. Likewise, to state (p. 108) that "the only plausible theory of stimulation and response is a colloidal theory that involves the assumption of marked viscosity changes within the protoplasm" is to ignore the work of numerous observers in the field of nerve and muscle activity.

L. R. Prouty and J. D. Hardy ably cover the techniques of temperature measurement. The section on "Theory of the Master Reaction" contains some misconceptions of Crozier's views. "Sharing" of control of frequencies (e.g., heart beat) by several processes with different μ's is impossible—in that event, Arrhenius plots concave upward would necessarily be common. Only three have been found, and their mechanism is understood; μ sometimes changes in the range of free reversibility but not always. Crozier did not conceive of simple successive reactions as determining apparent abrupt change of μ. It was early pointed out that these abrupt changes, when they occur, cluster at particular critical temperatures, and that this denotes physical change in the reaction matrix.

The chapter on bioelectric measurements, by H. J. Curtis, fills a real need. In the material on ultrasonics, it would have been more helpful to point out the practical biological significance of the theoretical considerations of ultrasound; for example, reflection coefficients are concisely covered, but nothing is said about cellular or tissue morphology where this might appear. In Chapter 12, before dealing with technical aspects, the author considers the economic and personnel factors involved in the acquisition and operation of an expensive and space-consuming instrument like the electron microscope. Another chapter discusses the factors involved in setting up a radiochemical laboratory.

There is no separate treatment of the basic problem of cell permeability, nor an introduction to methods of mathematical biophysics. A special chapter might well have been devoted to the cathode-ray oscilloscope, one of the most versatile tools in the biophysical laboratory.

The volume should prove useful for the worker who, in seeking the solution to his problem, wishes to survey the potentialities of different biophysical techniques.

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University of Pennsylvania

News and Notes

London Conference on Optical Instruments

Stanley S. Ballard

Physics Department, Tufts College, Medford, Massachusetts

This conference, with a membership of 250, was held at Imperial College, London, July 19–26. Although the great majority of the attendants were from the United Kingdom, 14 other countries were represented. The conference was limited to practical rather than theoretical questions, and it was further constrained to symposia on reflecting microscopes, reflecting telescopes, phase-contrast microscopes, spectrophotometers, gratings and grating instruments, photographic and projection lenses, and new optical materials. The manuscripts presented will be published in a volume by Chapman and Hall, Ltd. (John Wiley and Sons, Inc.), late this winter.

A significant feature of the conference was the opportunity provided to discuss the papers, and many important contributions were made in the course of the discussions. For instance, in the session on reflecting microscopes it was made clear that there is much activity, especially in England, the U. S., and Holland, on the designing of catadioptric systems, where the reflecting surfaces may be either spherical or aspherical. The applications of reflecting microscopes in biophysics and biochemistry are numerous and appear to be increasing at a rapid rate, probably largely because of the greater effectiveness of these systems in ultraviolet work over the conventional refracting systems.

Phase-contrast is another technique that is achieving wide use in microscopy. A new accessory was presented by M. Françon, of the Institut d'Optique of Paris, which permits the ready conversion of an ordinary microscope for phase-contrast use.

In a session on spectrophotometers it was emphasized that this instrument must now be regarded as a standard analytical tool for the monitoring and the control of appropriate industrial color processes rather than just an academic research item. It was indicated that the future trend in the design of spectrophotometers will be in the adaptation of the simpler single-beam instruments for double-beam use, rather than in the construction of more complicated double-beam or memory-device, single-beam instruments. Two methods for effecting this simplification have already been developed, at least partially: one by Halford and Savitzky, of Columbia University, employing phase discrimination, and the other by a group at the University College, Southampton, England, using different chopping frequencies for the sample and the comparison beams and an electronic method of balancing out the comparison signal.

The new echelle gratings, which have been developed at the Massachusetts Institute of Technology and the Bausch and Lomb Optical Company, were described to an interested audience. These high-resolution gratings are best used in conjunction with an ordinary spectrograph, where they increase the useful dispersion by a factor of 10–50 with very little decrease in photographic speed. A method of achieving higher disperson and resolution, using a conventional diffraction grating two or three times over by reflecting the light back in the "blaze" direction, was described by Hulthén of Sweden. A new method for making high-quality plane diffraction gratings is being developed at the National Physical Laboratory in England, following the suggestions of Sir Thomas Merton. It employs an ingenious method of correcting the periodic errors of the ruling-engine screw. The series of elaborate tests developed for testing the quality of the gratings is particularly noteworthy, but can only be fully appreciated when one has the opportunity of examining the setup. Plans for the large astronomical telescope for Great Britain were described and were the subject of much discussion. This, apparently, is a field in which it is considered dangerous to follow any but the conventional instrumental pattern because of the large amount of money involved in the building of large telescopes. Nevertheless, the British are starting out in a somewhat new direction with their dual-purpose telescope.

The use of combined refracting-reflecting optical systems in a high-precision theodolite was demonstrated by Lotmar of Switzerland. The resulting compactness and high optical quality of this system commend it for further study, not only for transits but also for high-powered military telescopes.

It seemed to the writer that the outstanding features of this excellent conference were the restriction of the subject matter to a few important items, the skillful scheduling of papers and allowance for adequate (and sometimes previously planned) discussion, the inspiring leadership provided by the several chairmen during discussion periods, and the sustained interest of the conference members throughout the five days of meetings. The contrast with some of our crowded, multipapered, simultaneous-sessioned scientific meetings is too apparent to require comment—it must be true that useful, although quite different, purposes are served by both types of meetings.

The Thirteenth Meeting of the Meteoritical Society

John A. Russell

Department of Astronomy, University of Southern California, Los Angeles

Meteoriticists from Michigan to California convened at Flagstaff, Arizona, on September 5 for the 13th meeting of the Meteoritical Society. Host of the society for the sessions on September 5 and 6 was the Museum of Northern Arizona, whose director, Harold S. Colton, extended the visitors every courtesy.

In the course of the two-day program, 27 papers were presented on such varied topics as direct and spectrographic observations of meteors, laboratory investigations of high-speed impact, air drag on cubes at high Mach numbers, mineralogical analyses of a number of meteorites—including several old Japanese falls—anthropological aspects of meteorites, recently discovered terrestrial craters of possible or probable meteoritic origin, subsurface studies at the Barringer Meteorite Crater, a proposed college curriculum in meteoritics, age determination of metallic meteorites through their helium content, meteoritical great circle problems, phenomena erroneously attributed to meteorites, a lost meteorite, and an estimate of the energy of the great Siberian meteorite based on the theory of atomic clouds.

The guest speaker at the society dinner, which followed the sessions of the second day, was Assistant Director E. D. McKee, of the Museum of Northern Arizona. His illustrated lecture on shooting the rapids through the Grand Canyon of the Colorado was an enjoyable diversion. It was followed by a showing of motion pictures of solar prominences filmed at the Harvard Observatory Station at Climax, Colorado.

The third day of the meeting was spent at the Barringer Meteorite Crater at the invitation of its owners, The Standard Iron Company of Philadelphia, and its curator, Theodore Johnson. A general exploration of the crater from its floor to areas well outside its rim was made during the morning. After lunch, a closing session was held on a promontory overlooking the crater. The high light of the afternoon was the report of the retiring president of the society, Arthur S. King. Dr. King outlined the notable advances in meteoritics during the past four years and expressed to President-elect L. F. Brady, curator of geology at the Museum of Northern Arizona, his best wishes and his confidence that the progress of the last four years would continue through Dr. Brady's administration.

About People

G. Lyman Duff, dean of the Faculty of Medicine, McGill University, will deliver the 13th annual Louis Gross Memorial Lecture, sponsored by the Montreal Clinical Society, on October 25 at the Jewish General Hospital in Montreal. Dr. Duff's subject will be "The Pathogenesis of Atherosclerosis."

William F. Ehret, professor of chemistry at New York University, is on leave for the academic year 1950–51 and is serving as visiting professor at the University of Hawaii.

Recent appointments to the staff of the Department of Physics, Univrsity of Connecticut, are **Edgar Everhart**, assistant professor, and **Otis R. Gilliam**, instructor. Dr. Everhart was previously instructor in physics at Dartmouth College and a staff member of the Radiation Laboratory at MIT. Dr. Gilliam comes from the Graduate School at Duke University.

J. J. Galloway, professor of stratigraphy and paleontology at Indiana University, is on sabbatical leave for the fall semester, in order to complete his study of the stratigraphy and paleontology of the Harrodsburg (Mississippian) limestone of Indiana. **Tom G. Perry**, of the University of Toronto, has been appointed instructor in geology to teach courses in stratigraphy and invertebrate paleontology.

Elmer Hutchisson, of Case Institute of Technology, Cleveland, will serve as acting president during the leave of absence of **T. Keith Glennan**, who has accepted an appointment as a member of the Atomic Energy Commission. Dr. Hutchisson will continue in his position as dean of the faculty and director of research and of the Graduate Division.

William B. Nutting, of Cornell University, **Harold Rauch**, of Brown University, **Bronislaw M. Honigberg**, of the University of California, and **Lyle C. Dearden**, of the University of Kansas, have been appointed instructors in the Department of Zoology at the University of Massachusetts.

Paul Marsh Pitman will be inaugurated president of the College of Idaho, Caldwell, on October 14. **L. A. Williams** has been acting president.

I. I. Rabi, professor of physics at Columbia University, has been appointed to membership on the U. S. National Commission for Unesco. As a member of the U. S. delegation to the Unesco General Conerence in Florence last spring, Dr. Rabi was largely responsible for the adoption of a resolution to assist and encourage the formation and organization of regional research centers and laboratories in order to increase the international collaboration of scientists.

Ada Chree Reid was elected president of the Medical Women's International Association at its sixth congress in Philadelphia. Dr. Reid

is editor of the *Journal of the American Medical Women's Association* and attending cardiologist at New York Infirmary.

Warner F. Sheldon, assistant professor of pathology in the University of Pennsylvania School of Medicine, has been elected director of the Mount Desert Island Biological Laboratory, Salisbury Cove, Maine. Dr. Sheldon succeeds **J. Wendell Burger,** associate professor of biology at Trinity College.

Thomas C. Watkins, professor of economic entomology at Cornell University, has gone to the University of Miami, Coral Gables, Fla., to complete a sabbatical leave study. Dr. Watkins will devote his major attention to studies and collections of insect pests of subtropical plants, including citrus fruits. He is making his headquarters at the Subtropical Horticultural Farm recently established at the university.

Visitors

Recent visitors at the U. S. Geological Survey, Washington, D. C., were: **Leslie Kent,** Geological Survey, Union of South Africa; **B. G. Escher,** Leyden University, Netherlands; **J. H. F. Umgrove,** Waassenaar, Netherlands; **Felix Andres Vening-Meinesz,** Meteorological Institute, Netherlands; **J. F. Cox,** Free University, Brussels; **Jean Goguel,** Institute of Geophysics, Geology and Mining, Paris; and **C. E Tilley,** University of Cambridge, England.

Recent visitors at the National Bureau of Standards were: **E. C. Bullard,** head of the National Physical Laboratory, Teddington, England; **Pierre Fleury** and **Maurice Françon,** of the Institut d'Optique, Paris; **M. Caneppa** and **Bruno de Finetti,** of the Istituto Nazionale per le Applicazioni del Calcolo, Rome; **Jacques F. Cox,** University of Brussels; **Ryosuke Hama,** Institute of Science and Technology, University of Tokyo; **Marc Kampe de Feriet,** École Centrale de Paris; **Hugh O'Neill,** University College, Swansea, Glamorganshire, Wales; **Giulio Racah,** The Hebrew University, Jerusalem; **Ivan A. Rubinsky** and **Elie Rubinsky,** American University, Beirut; **Elie Roubine,** L'Ecole Supérieure d'Electricité, Paris; and **Dennis Brown,** associate professor, Auckland University College, New Zealand.

Grants and Awards

The Hematology Research Foundation, of Chicago, recently awarded the following fellowships: **The Ruth Berger Reader Fellowship** to Fern L. Stevenson, at Hektoen Institute for Research, Cook County Hospital; the **Robert L. Goldblatt Fellowship** to Abe Oyamada, at Mount Sinai Hospital; and the **Dr. Raphael Isaacs Fellowship** to Aaron M. Josephson, at Michael Reese Hospital.

William F. Little, engineer in charge of the Photometric Department, Electrical Testing Laboratories, New York City, has received the 1950 **Illuminating Engineering Society Medal,** awarded annually in recognition of achievement which has furthered the profession, art, or knowledge of illuminating engineering in the field of engineering, design, applied illumination, optics, ophthalmology, lighting research, education, or administration and management.

Colleges and Universities

A center for advanced training and research in zoology is being developed at the **University of Illinois** in its museum of natural history. Latest additions to the educational collection are 450 specimens of animal life from the Huachuca Mountains of Arizona, collected by Donald F. Hoffmeister, museum curator, and Richard Van Gelder, of Ft. Collins, Colo., graduate student at Illinois, in a month-long summer trip. Added to 350 specimens from the Huachuca region already at the University, they provide the greatest collection of mammals from the area assembled in any museum.

The University of North Carolina is offering postgraduate medical courses for practicing physicians in the state, sponsored by the School of Medicine and the Extension Division of the university. The courses will be given at various towns throughout the state. Speakers for two courses arranged for this fall include Louis A. M. Krause, University of Maryland, Milton L. McCall, Jefferson Medical College, Eugene B. Ferris and A. A. Weech, University of Cincinnati, H. Houston Merritt, Columbia University College of Physicians and Surgeons, Bentley P. Colcock, The Lahey Clinic, E. T. Bell, University of Minnesota, Eugene Stead, Duke University, and Harold D. Green, Bowman Gray School of Medicine.

The Stritch Medical School, Loyola University, Chicago, presented its second televised postgraduate conference in obstetrics and gynecology, September 25–29, at the Lewis Memorial Maternity Hospital. The program was made possible through the cooperation of E. R. Squibb & Sons and the Radio Corporation of America. Among those taking part were William J. Dieckmann, University of Chicago, Ralph A. Reis and Ronald R. Greene, Northwestern University, and Harry A. Oberhelman and John J. Madden, of Stritch Medical School.

The Institute for Fluid Dynamics and Applied Mathematics, University of Maryland, is sponsoring a series of public lectures and seminars during the fall academic term. Six lectures will be given by Joseph-Marie Kampe de Feriet, professor of mathematics, University of Lille, who is visiting research professor at the institute. Dr. de Feriet's first group of lectures, to be held October 17–19, will be on aspects of "Spectrum of Turbulence and Diffusion." The second group of lectures will be on "Atmospheric Turbulence," to be given December 12–14. Weekly seminars on "Statistical Theory of Turbulence" will be conducted by Dr. de Feriet, and Alexander Weinstein, research professor at the institute, will conduct seminars on "Hilbert Space and Theory of Vibrations." Sydney Goldstein, professor of mathematics,

Institute of Technology, Haifa, gave a series of lectures during September and early October. Further information about the seminars, lectures, and colloquia of the institute may be obtained from Raymond J. Seeger, acting director of the institute, College Park, Md.

A special committee on skin metabolism and regeneration has been established at the **University of Texas Medical Branch**, Galveston, to correlate studies in these fields with particular reference to the management of burns and radiation injury. Chairman of the committee is Clarence S. Livingood, professor of dermatology and syphilology.

Industrial Laboratories

The Ercona Corporation, of New York City, has been appointed exclusive American agent for Carl Zeiss optical instruments, binoculars, and photographic lenses. A scientific instrument division has been set up by the corporation under the direction of Alfred Boch. A broad range of Zeiss instruments is now available for science and industry in America.

The Fairchild Recording Equipment Corporation of Whitestone, New York, has manufactured a control track generator which superimposes a high-frequency signal on the magnetic tape simultaneously with the sound track. Available for immediate delivery.

Instrument News, published quarterly by **The Perkin-Elmer Corporation,** Glenbrook, Conn., in the interests of furthering research, material analysis, and production through modern optical instrumentation, is available on request.

Fred S. Carver, Inc., 345 Hudson Street, New York 14, manufacturer of hydraulic equipment, has issued a catalogue introducing the latest edition of the well-known Carver laboratory press for research and development.

Bell Telephone Laboratories has developed a new technique for photographing the pattern of sound waves. The method will be used for studying waves from communications equipment and for observing microwave radio wave patterns.

Bausch & Lomb Optical Co. will exhibit a new metallograph at the National Metal Show in Chicago, October 23–27.

Scientific Glass Apparatus Co. has released *What's New for the Laboratory, No. 10,* containing descriptions of many new or improved laboratory aids.

A new technical booklet describing the use for **Hercules Powder Company's** Vinsol resin in the production of Buna N cements and adhesives is now available.

Lanco Apparatus News, published by Arthur S. La Pine & Company, 121 West Hubbard Street, Chicago 10, has been expanded to 8 pages covering laboratory supplies and reagents and industrial chemicals.

Radio Corporation of America will exhibit 50 years of electronic engineering advances at the Mid-Century Exposition in Dallas, Texas. October 7–22.

The Eastman Kodak Company's *Kodak Color Handbook* provides a handy reference and guide for advanced amateur and professional photographers in 248 pages at $4.00.

Meetings and Elections

St. Francis Sanitorium for Cardiac Children is presenting seminars on **the nature and treatment of rheumatic fever,** on the first Tuesday of each month, October 10 to May 8, 1951. The subjects for discussion each month are:

Oct. 10—Nature of Rheumatic Fever.
Nov. 14—Experimental Rheumatic-like Disease.
Dec. 12—Present Concepts Regarding the Mechanism of Heart Failure.
Jan. 9—Treatment of Rheumatic Fever with Cortisone and ACTH.
Feb. 13—Oxygen Therapy ' 1 Heart Disease.
Mar. 13—Salt Metabolism and Cardiovascular Disease.
Apr. 10—Treatment of Congestive Failure in Rheumatic Heart Disease.
May 8—Methods for Measuring Cardiodynamics.

Further information may be obtained from Reverend Mother Superior, F.M.M., St. Francis Sanitorium for Cardiac Children, Roslyn, Long Island, N. Y.

An institute on coastal engineering, sponsored by the Departments of Engineering and the Division of Engineering Extension, University of California, Berkeley and Los Angeles, will be held October 11–14, at the Municipal Auditorium, Long Beach. The conference is planned to summarize current information and techniques for engineers engaged in design, construction, operation, and maintenance of coastal works. Topics for discussion include fundamentals of wave action, development of basic design data, natural and artificial movement of sediment, site criteria for harbors and other coastal works, and design and construction of structures exposed to wave action. Programs may be obtained from Department of Institutes and Lectures, University Extension, University of California, Los Angeles 24.

The American Dietetic Association will hold its 33rd annual meeting in Washington, D. C., October 16–20. Winthrop M. Phelps, medical director, Children's Rehabilitation Institute, Baltimore; O. Spurgeon English, head of the Department of Psychiatry, Temple University School of Medicine and Hospital, Philadelphia; John R. McGibony, chief, Division of Medical and Hospital Resources, USPHS; William S. Schram, Veterans Administration, Newark; and C. Glen King, scientific director, Nutrition Foundation, New York City, will be among the speakers. A number of sessions will be concerned with food technology, institution management, and professional education.

The fourth general assembly of the World Medical Association will meet in New York City, October 16–21. The association is composed of national professional groups in 39 countries, and nearly all of these will be represented at the meeting. Objectives of the association are to promote closer ties among the national medical organizations, to

maintain the honor and protect the interests of the medical profession, to study and report on professional problems in different countries, to exchange matters of interest to the profession, to establish relations with other health groups, to assist all peoples of the world to attain the highest possible level of health, and to promote world peace. A number of technical papers will be presented at the scientific session to be held on October 18. Alfred Blalock, surgeon-in-chief, Johns Hopkins Hospital, will discuss advances in heart surgery. The therapeutic uses of blood and blood derivatives will be described by Louis K. Diamond, medical director of blood banks, American National Red Cross. Effects of stresses on human organs will be discussed by Hans Selye, director of the Institut de Medicine et de Chirurgie Experimentales, Université de Montreal, Quebec. Alfred F. R. Andresen, consultant in gastroenterology, Flushing Hospital, Brooklyn, will review diseases of the stomach and intestine. A conference of medical editors of the world will be held on October 21, presided over by Morris Fishbein, editor of the *World Medical Association Bulletin.*

A two-day program, devoted to an analysis of **recent developments in the applications of radioisotopes to biomedical problems** will be conducted at the University of Colorado Medical Center, Denver, on October 19 and 20. Talks will be presented on the interaction of radiation with biological systems, problems of protection and dosimetry in biological applications of isotopes, recent biochemical developments utilizing isotopes, the use of I^{131} as a clinical test for thyroid function, therapeutic applications of radiophosphorus and radioiodine in various clinical conditions, and progress in clinical applications of various isotopes. Guest speakers will include Rulon Rawson, Sloan-Kettering Institute, New York City, Paul Aebersold, George Manov, and Allen Lough, Isotopes Division, Atomic Energy Commission, Oak Ridge, and John Z. Bowers, Division of Biology and Medicine, Atomic Energy Commission. The course will include demonstrations of isotope procedures currently employed in biomedical research and clinical practice. The course is open to physicians and physical and biological scientists. The registration fee is $5.00, and the tuition is $20.00. Applications should be sent to Director of Graduate Medical Education, University of Colorado Medical Center, 4200 E. Ninth Ave., Denver 7.

The eighth "Frontiers in Chemistry" lecture series, co-sponsored by the International Society of the Friends of the Kresge-Hooker Library and Wayne University Department of Chemistry, will take place on Monday evenings at 7:00 P.M. in Science Hall on the Wayne campus, Detroit, Mich. Lecturers and the dates of their appearance are:

October 16–M. G. Mellon, Purdue University
October 23–L. L. Quill, Michigan State College
October 30–C. G. Swain, Massachusetts Institute of Technology
November 6–R. C. Fuson, University of Illinois
November 13–T. F. Young, University of Chicago
November 20–I. M. Kolthoff, University of Minnesota
November 27–Henry A. Lardy, University of Wisconsin
December 4–R. T. Arnold, University of Minnesota

The noncredit registration fee for the series is $5. Qualified persons may arrange for graduate credit of one or two hours. Additional information may be obtained from George H. Coleman, professor of chemistry at Wayne.

Abstracts of all lectures will be provided registrants in advance. A dinner at which the speaker will be guest of honor will take place at the University's Student Center at 5:30 P.M. on each of the program nights. All registrants are invited, but should make advance reservations.

An international colloquium on Calculating Machines and Human Thought will be held in Paris January 8–12, 1951, under the sponsorship of Le Centre National de la Recherche Scientifique. American scientists invited to attend are H. H. Aiken, Harvard University; E. W. Cannon, National Bureau of Standards; Norbert Wiener, Massachusetts Institute of Technology; and E. C. Berkeley, Edmund C. Berkeley and Associates, New York City.

The second high frequency measurements conference, sponsored jointly by the American Institute of Electrical Engineers, the Institute of Radio Engineers, and the National Bureau of Standards, will be held in Washington, D. C., January 10–12, 1951. Conference headquarters will be at the Hotel Statler, and the technical sessions will be held in the auditorium of the Department of Interior.

The Illuminating Engineering Society elected the following officers at its recent national technical conference: president, Walter Sturrock, General Electric Co.; vice president, E. M. Strong, Cornell University; treasurer, R. F. Hartenstein, Ohio Edison Co.; and general secretary, A. H. Manwaring, Philadelphia Electrical & Mfg. Co.

The Plant Science Seminar elected the following officers for 1950–51, at its annual meeting in Boston, August 24–30: chairman, Heber W. Youngken, Jr., University of Washington; vice chairmen, Paul D. Carpenter, University of Illinois, and Carl H. Johnson, University of Florida: secretary, Edward P. Claus, University of Pittsburgh; and members of the executive committee, Elmer L. Hammond, University of Mississippi, and J. Allen Reese, University of Kansas.

Tables of Nuclear Data, recently compiled by the National Bureau of Standards, are now available. The initial volume, together with supplements that will follow at six-month intervals, will present a comprehensive collection of experimental values of half-lives, radiation energies, relative isotopic abundances, nuclear moments, and cross sections. Decay schemes and level diagrams,

more than 125 of which are included in the tables now ready, will be provided wherever possible. References to over 2,000 original papers make it possible for the research worker to evaluate the details of previous investigations and to design experiments to resolve existing discrepancies. The publication is available from the Superintendent of Documents, U. S. GPO, Washington 25, D. C., at $4.25 a copy, which includes the price of three supplements. Remittances from foreign countries must be made in U. S. exchange and must include an additional sum of one-third the publication price to cover mailing costs.

The U. S. Naval Ordnance Test Station at Inyokern, Calif., is establishing a group of mathematicians and statisticians for weapons evaluation work, and is recruiting technical personnel for the work. There are also openings for recent graduates and theoretical physicists with specialized interests in solid state physics, atomic physics, fluid mechanics, hydrodynamics, aerodynamics, and other fields of classical physics. Full information can be obtained from J. B. Hamilton, Head, Professional Placement Branch, U. S. N. O. T. S., Inyokern, China Lake, Calif.

Presidential approval of the omnibus appropriations bill for 1951 makes available to the **Public Health Service** $3,600,000 for research with cortisone and ACTH. The entire sum is allocated for research grants to nonfederal institutions and scientists. The work will be directed toward evaluating preliminary results already achieved with these compounds and toward further investigation of their possible dangers and benefits. Grants will be made largely for study of the compounds in relation to arthritis and cancer, mental and neurological, metabolic, and cardiovascular diseases, as well as for basic laboratory studies on the general biological effects of the compounds.

In carrying out the program, the PHS will continue to cooperate with the Department of Agriculture in seeking plant sources from which cortisone and other steroids can be obtained. Although chemical synthesis and screening of new compounds are being conducted largely under the auspices of private industry, some of the allocated funds will be available for these lines.

The grants will be administered through the service's Research Grants and Fellowships Division of the National Institutes of Health. Applications will be evaluated and reviewed by one or more of 22 specialized study sections. The National Advisory Council, a nonfederal scientific group, will make the final recommendation. The deadline for receipt of applications is *November 1*.

A new international "yardstick," calculated from the wavelength of light waves emitted from bombarding a rare form of atomically produced mercury, is being developed by Kenneth B. Adams, of the Westinghouse Research Laboratories, and Kevin Burns, astronomer at the Allegheny Observatory in Pittsburgh, in collaboration with the National Bureau of Standards and scientists in France and England. This standard, on which all international measurements of length can be based, will be officially adopted only after its measurement is confirmed by at least three laboratories working independently in three different parts of the world.

The second annual Conference of Midwestern Parasitologists has established a coordination committee for compilation of a list of **parasitological research laboratories** of all types in the midwestern area and a cross-indexed check-list of the cultures of parasitic protozoa, helminths, mollusks, and arthropods maintained in these laboratories. This listing will coordinate and facilitate the exchange of material for both teaching and research purposes. A digest of the existing laws and regulations enforced by the U. S. Public Health Service and Department of Agriculture governing the shipment of cultures, and a manual on maintenance, shipment, handling, and transfer of parasitic cultures will also be sent out with the check-list. If all laboratories between the Rocky Mountains and the Alleghenies that have not received notice of the listing will write Dr. H. Elishewitz, Department of Microbiology and Public Health, Chicago Medical School, 710 S. Wolcott Ave., Chicago 12, Ill., their names will be included on the final list.

A new spectroscope, the Todd Spectranal, is now available, permitting rapid, accurate macro- or microanalysis of 33 elements. Only a few milligrams of the sample are required, and these are completely recovered after analysis. The spectroscope is designed so that the element is excited by controlled voltage and amperage through two platinum electrodes in a glass condenser chamber. This obviates the need for cool gas flames, hot arc, or spark excitation. The instrument permits visual analysis, eliminating the need for photographic equipment, and rapid identification can be made by laboratory personnel. Further information about the instrument is available from Meyer Scientific Supply Company, 221 Atlantic Ave., Brooklyn 2, N. Y.

Recently Received

Absolute Measurement of Resistance by the Wenner Method. James L. Thomas *et al.* National Bureau of Standards Research Paper RP 2029. U. S. GPO, Washington 25, D. C. 30 cents.

The Geiger-Müller Counter. National Bureau of Standards Circular 490. U. S. GPO, Washington 25, D. C. 20 cents.

Sterling-Winthrop Research Institute. John B. Watkins Company, New York City.

Thermal Expansion of Solids. Cir. C486, National Bureau of Standards. U. S. GPO, Washington 25, D. C. 20¢.

Table of Powers of Complex Numbers. Herbert E. Salzer. AMS 8, National Bureau of Standards. U. S. GPO, Washington 25, D. C. 25¢.

Density of Solids and Liquids. Cir. C487, National Bureau of Standards. U. S. GPO, Washington 25, D. C. 20¢.

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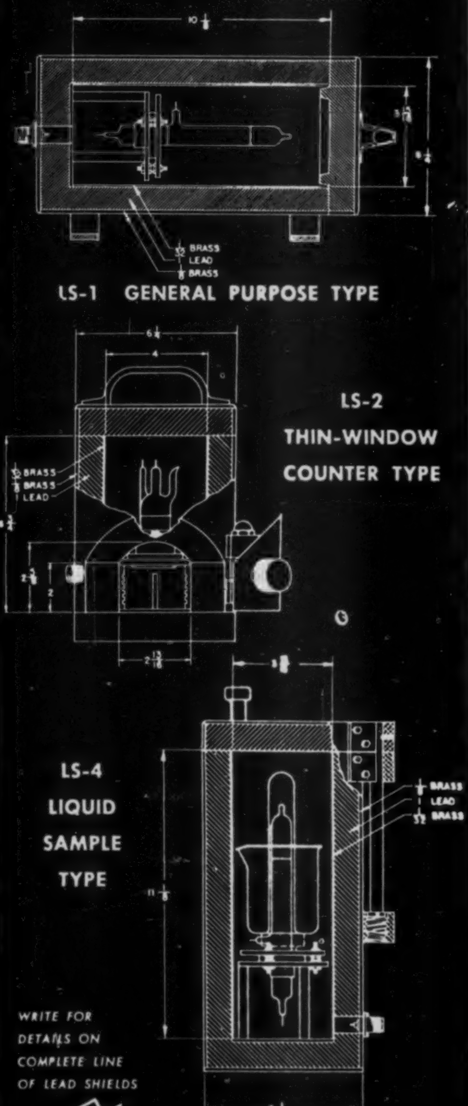

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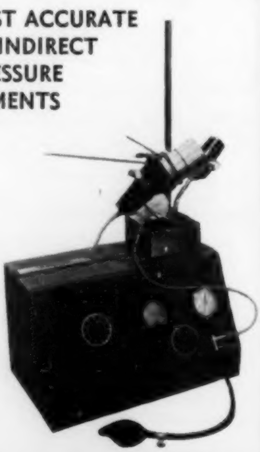

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1. Rate: 15¢ per word, minimum charge $3.00 for each insertion. If desired, a "Box Number" will be supplied, so that replies can be directed to SCIENCE for immediate forwarding. Such service counts as 10 words (e.g., a 25-word ad, plus a "Box Number", equals 35 words). All ads will be set in regular, uniform style, without display; the first word, only, in bold face type.

For *display* ads, using type larger or of a different style than the uniform settings, enclosed with separate border rules, the rate is $16.00 per inch; no extra charge for "Box Numbers".

2. Advance Payment: All Personnel Placement ads, *classified* or *display*, must be accompanied by correct remittance, made payable to SCIENCE. Insertion can not be made until payment is received.

3. Closing Date: Advertisements must be received by SCIENCE, 1515 Mass. Ave., N.W., Washington 5, D. C., together with advance remittance, positively not later than 14 days preceding date of publication (Friday of every week).

POSITIONS WANTED

Biochemist; Ph.D., five years, nutritionist, state health department; twelve years, professor of biochemistry, university medical school; past several years, cancer research; for further information, please write Science Department, Medical Bureau (Burneice Larson, Director) Palmolive Building, Chicago. X

Chemist & Administrator. 31 Good appearance. Versatile and dependable. M.S. Excellent training. 10 years laboratory experience. Biochemistry- vitamins- microbiological assays. Foods and pharmaceuticals. Box 310, SCIENCE. X

POSITIONS OPEN

Biologist: Require a man under 35 years of age with M.S. or equivalent in training or research experience to carry out bacteriological work and tests involved with germicide, detergent, or repellent products. Foreign and U. S. field trips necessary to assist in the research work on palm culture, hybrids, and new natural waxes. Write fully giving detailed background, salary requirements, and furnish inexpensive photo of yourself. All replies held confidential. W. S. Dowman, S. C. Johnson & Son, Inc., Racine, Wisconsin. 10/6

Microbiologist: Ph.D. Fundamental training in soils, fermentations. Research and administrative experience in antibiotics. Excellent opportunity. Location New York City. Box 307, SCIENCE. 10/6

Ontario Research Foundation requires research fellows in (a) Climatology, open especially to graduates in botany and agronomy; and (b) Physiography, open to graduates in geology, soils and geography. Application forms may be obtained from The Director, Ontario Research Foundation, 43 Queen's Park, Toronto 5, Canada. 10/13

Positions Open:
(a) **Mycologist and virologist** qualified for professorial appointments, department of infectious diseases, university medical school; physicians of outstanding attainments in academic field required. (b) **Biochemist**; Ph.D., interested in doing research dealing with blood enzymes, steroid hormones, growth hormone assay and, also, two research assistants with Bachelors' or Masters' degrees; modern well-equipped research laboratories, teaching institution; Midwest. (c) **Bacteriologist**, Ph.D., to work on respiratory infection from standpoint of pure research and, also, bacteriologist experienced in medical bacteriology, chemical engineering or related industrial experience; research department, university medical school. (d) **Senior pharmacologist**; Ph.D. or M.D. with pharmacological research experience; should be qualified to initiate and develop pharmacological research program; pharmaceutical company; East. (e) **Biochemist**; research work, involving study of effects of x-rays on dilute solutions of crystalline enzymes; research institution. S10-1 Science Division, Medical Bureau (Burneice Larson, Director) Palmolive Building, Chicago. X

Research Associate in Virology, Ph.D., or equivalent training; experience in virus work, and immunology; Virus Research Department, University Medical School. Box 309, SCIENCE. X

Wanted: Biochemist to join staff of the Department of Obstetrics and Gynecology, University of Colorado for special work in hormone study. Those interested please communicate with Dr. E. Stewart Taylor, 4200 East Ninth Avenue, Denver 7, Colorado. Salary $5000–6000 per year. X

The Market Place

For "Charges & Requirements" see pg. 14, Sept. 29th issue.

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